January 1982
Final Report

DOT HS-806-199

U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

The Role of Alcohol, Marijuana, and Other Drugs in the Accidents of Injured Drivers

Volume 1—Findings

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Contract No. DOT HS-5-01179
Contract Amount $496,165

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. DOT-HS-806 199	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle The Role of Alcohol, Marijuana, and Other Drugs in the Accidents of Injured Drivers, Volume 1, Findings		5. Report Date January 1982
		6. Performing Organization Code
7. Author(s) K. W. Terhune		8. Performing Organization Report No. ZS-5769-V-1
9. Performing Organization Name and Address Calspan Field Services, Inc. 4455 Genesee Street Buffalo, New York 14225		10. Work Unit No. A03
		11. Contract or Grant No. DOT-HS-5-01179
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration 400 Seventh Street, S.W. Washington, D.C. 20590		13. Type of Report and Period Covered Final Report June 1975 - January 1982
		14. Sponsoring Agency Code

15. Supplementary Notes

Report is in two volumes. Volume 2 is Appendices.

16. Abstract Using samples of blood obtained from 497 injured drivers at a Rochester, NY hospital, this study determined the incidence rates of alcohol, THC (marijuana agent), and other drugs. Accident data (police reports, driver interviews) were also collected, and analyses determined driver culpability rates, collision types, and crash circumstances involving alcohol and certain drugs. Main substances found were alcohol (25%), THC (10%) and tranquilizers (8%); 38% of the drivers had alcohol or some other drug tested for in their systems. Culpability rates were: 74% for intoxicated drivers, 53% for THC-only drivers, 34% for drugfree drivers, and 22% for tranquilizer-only drivers. Alcohol-involved crashes were predominantly single vehicle accidents, followed by striking vehicles in head-on and rearend impacts. No unique THC or tranquilizer collision types were found. Circumstances overrepresented in alcohol crashes were curves, occurrence on weekends, occurrence between midnight-6AM, unlighted streets, and non-intersection locations. "Alcohol accident types" were identified, e.g. single-driver crash occurring midnight-6AM on a curve (95% alcohol involvement). Police reporting of alcohol involvement was also analyzed. Possible roadway and vehicle countermeasures to reduce impaired-driver accidents were suggested. Other recommendations addressed police alcohol detection and NASS or FARS monitoring of alcohol involvement. Further study clarifying the crash roles of THC and tranquilizers in fatal and non-fatal crashes was considered essential.

17. Key Words Alcohol accidents; drug crashes; drinking drivers; alcohol countermeasures; driver culpability	18. Distribution Statement Document is available through the National Technical Information Service Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	194	

Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). [illegible] tables, see [illegible] Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

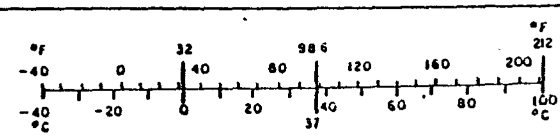

Figure 3. - METRIC CONVERSION FACTORS

FOREWORD

This is the final report of a study conducted by Calspan Field Services, Inc. (CFSI) for the National Highway Traffic Safety Administration under Contract DOT-HS-5-01179.

Initially the project was proposed by Mr. Kenneth Perchonok, who directed the project through Phase 1, a planning phase. After Mr. Perchonok's leaving CFSI, Dr. Kenneth W. Terhune assumed the direction of the project through Phases 2 and 3. These phases comprised the data collection, analysis, and final report components of the project.

The sampling of drivers was carried on at Rochester General Hospital under the auspices of the University of Rochester Accident Investigation Unit, directed by John D. States, M.D.. Blood samples obtained from the drivers were analyzed at the University of Utah Center for Human Toxicology, under the project direction of Michael Peat, Ph.D..

Assisting in project coordination at CFSI were Mr. Thomas A. Ranney and Mrs. Joanne M. Fletcher.

Readers interested in only a brief summary of this report should refer to the Technical Summary, which is a separate document. For a somewhat longer review of the essential findings, conclusions, and recommendations, with minimal data, the reader may review Chapter 10 of this longer report. Summaries of the main findings may also be found at the end of each main section within the results chapters.

This report has been reviewed and approved by:

John W. Garrett
John W. Garrett, Manager
Accident Research Division

ACKNOWLEDGMENTS

In this project involving three private research organizations, two government agencies, fourteen police agencies, and a hospital, contributions were made by a large number of people. Appreciation is expressed to all who participated, and a few who made unique contributions will be acknowledged here. For any unsung heroes whose special services may have gone unnoticed, indebtedness is expressed.

Dr. John D. States, in addition to directing the project component at the University of Rochester Accident Investigation Unit, made a vital contribution by enlisting the participation of Rochester General Hospital after other hospitals had declined. Dr. States' staunch support helped maintain the project through difficult periods.

Dr. John Ricks of Carlysle Hospital in Pennsylvania was administrator of the Rochester General Hospital Emergency Department throughout the data collection. Dr. Ricks' enthusiasm, encouragement, and problem-solving counsel were invaluable.

Kenneth Perchonok has continued to provide helpful advice on the project since leaving Calspan Corporation to join the Institute for Research in Pennsylvania. His critique of the report draft was especially helpful.

Mr. Arthur L. Liebert, President of the Rochester General Hospital, provided the endorsement essential for the hospital's continued involvement in the project.

In the Emergency Department of the Rochester General Hospital, valiant efforts to maximize driver participation were made by: Ms. Mary Stritzel, Administrative Coordinator; Ms. Jeanette Merritt, Head Nurse; Ms. Jan Kaufman, Nurse Practitioner; Carolyn Kaslow, Head Secretary; and Team Coordinators Sheila Cohen, Linda Corbett, Barbara Crowley, Jacqueline Jablonski, Jacqueline Marcussi, Flora McEntee, and Darleen Randazzo.

The heads of all Monroe County police agencies willingly insured the cooperation of their departments. These included: Monroe County Sheriff William M. Lombard; Commissioner Thomas F. Hastings (Rochester); and Chiefs Clyde Bussey (East Rochester), Robert Henry (Brockport), William H. Frey (Irondequoit), Kenneth Hulbert (Webster), D. L. Norris (Wheatland), Gerald Phelan (Greece), Joseph D. Picciotti, Jr. (Fairport), Thomas V. Roche (Gates), Russell R. Ruhl (Ogden), and Eugene Shaw (Brighton). In addition, Sgt. Daniel Morgenthaller expedited the cooperation of Troop E., New York State Police. Mr. Daniel Labowitz, Chief of the Monroe County DWI Bureau, made valuable data available to the study.

At the National Highway Traffic Safety Administration, James C. Fell was Contract Technical Monitor. His unflagging conviction of the need for the study, and the efforts he made on its behalf, insured that the project reached fruition. Dr. Stephen D. Benson and Theodore E. Anderson provided needed support at crucial points throughout the project, and their reviews of the final report were found helpful.

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1. INTRODUCTION AND OBJECTIVES

Research has conclusively shown that alcohol impairment greatly increases a driver's chances of having a serious traffic accident. Carefully controlled studies indicate that an intoxicated driver is at least five to ten times more at risk of a fatal crash than is a sober driver. As a consequence, alcohol-involved drivers constituted about 60 per cent of fatally injured drivers in recent years. There can be little question that alcohol impairment is a highway safety problem deserving highest priority.

These findings come from a number of studies summarized in a comprehensive review of the state of knowledge on alcohol and highway safety (Jones and Joscelyn, 1978). While research thus delineates the scope and seriousness of the drinking-driver problem, it also can aid in the search for solutions. To date, the solutions put forth lie in two main directions. The first, and by far the predominant effort, aims at reducing the numbers of motorists driving under the influence of alcohol--the goal is "getting the drunk driver off the road." A host of activities such as increasing police apprehension of impaired drivers, launching public information campaigns, organizing citizen groups, and developing drunk-driver rehabilitation programs, have been employed in pursuit of the goal. While some successes have been claimed, drunk-driver accidents remain prevalent; the deterrence strategy, it seems, cannot be considered the only way to fight the war against drunk driving. A second strategy, hardly more than a hopeful idea as yet, is to make improvements in roads and vehicles that will reduce the chances of an impaired driver having an accident. This is a controversial concept which may become acceptable only for those improvements which will benefit all drivers, not just those irresponsible enough to operate a vehicle while under the influence. But the idea is being given a hearing, as when it was recently deliberated by the Governor's Alcohol and Highway Safety Task Force in the State of New York (1981). Handicapping this approach, however, is the lack of research showing specifically how alcohol is causing accidents.

The study reported here makes a contribution toward each of the two countermeasure directions. For the deterrence of impaired driving, the study identifies "alcohol accident types," suggesting a method which police might use to detect alcohol-impaired drivers in accidents. Toward the end of developing road and vehicle countermeasures, the study seeks to indicate apparent manifestations of alcohol impairment that lead drinking drivers into their accidents. Of concern here are not only driver behavioral errors, but also the features of vehicles and environment which impaired drivers find particularly hazardous. Once identified, the apparent errors and hazards can suggest countermeasures for further test and evaluation.

In addition to the alcohol-impairment problem, another potentially serious one is gaining attention--drivers impaired by drugs other than alcohol. Of concern are not only the so-called "recreational" (and illicit) drugs like marijuana and cocaine, but also medicinal substances like tranquilizers, "pain-killers," and anti-anxiety drugs. For better or worse, use of these substances has become common in the American society. Despite a great deal of publicity and research, so little is known about the role of drugs in highway crashes that the very question of whether a "problem" exists is debatable. In a comprehensive review of current knowledge on the subject, the University of Michigan's Highway Safety Research Institute (HSRI) reported: "Briefly stated, the extent to which drugs contribute to problems in highway safety is unknown." (Joscelyn et al., 1980, p. 11) Although HSRI found several experimental and epidemiological studies on the subject, all were sufficiently limited in scope or flawed in design to render doubtful the role of drugs in highway crashes. Even the most basic question of "the frequency with which drug-impaired drivers drive and are involved in crashes" could not be answered, concluded HSRI. Addressing that question provides another fundamental purpose of this report. Not only is the <u>incidence</u> of drug involvement in accidents examined, but their possible causal role in the accidents is explored.

Objectives

The following were the formal objectives of this research project performed for the National Highway Traffic Safety Administration.

(1) to determine the incidence of various specific drugs found in the blood systems of drivers who have had a motor vehicle accident and were treated for injuries at a hospital;

(2) to determine the behavioral errors committed in these accidents, the characteristics of the drivers, and various situational and environmental factors present in the accident that will be used to develop "alcohol accident types";

(3) to compare and determine any significant differences between drivers under the influence of alcohol vs. sober drivers in terms of "accident types," driver characteristics and behavioral errors;

(4) to conduct the same or similar analyses as above for any drug related driver group other than alcohol, if the incidence is large enough;

(5) to identify potential problem areas that may be useful for countermeasure development and any salient countermeasures relevant to the findings.

Later in this chapter these objectives will be translated into specific questions addressed by the study. The significance of the questions is best appreciated, however, by briefly reviewing the state of knowledge on alcohol and other drugs in highway safety. That follows next.

Background

Elsewhere, comprehensive reviews have examined the role of alcohol and other drugs in highway safety (Jones and Joscelyn, 1978; Joscelyn et al., 1980; Terhune, et al., 1980). While those sources provide a thorough background for the interested reader, it is useful here to highlight the main points of current knowledge upon which this research was based.

Substance incidence rates. At the current time, definitive knowledge of the degree to which drugs are involved in highway accidents is confined exclusively to alcohol. On the basis of a number of studies, Jones and Joscelyn (1978) showed that, on the average, alcohol involvement progressively increases with crash severity:

	Approximate Proportions of Drivers	
Accident Severity	Any alcohol (BAC > 0)	Intoxication (BAC $\geq$ 0.10%)
Property damage crashes (1 study)	16%	5%
Personal injury crashes (2 studies)	25%	11%
Fatally injured drivers (4 studies)	60%	47%

The results for fatally injured drivers were corroborated recently with data from the Fatal Accident Reporting System (FARS). In the states which tested for blood alcohol in 80 per cent or more of fatally-injured drivers,* 58.7 per cent of nontruck drivers had positive Blood Alcohol Concentrations (Terhune, et al., 1980). Regarding personal injury crashes, corroboration of the above figures was obtained in a study of injured drivers in New Brunswick, Canada (Warren et al., 1981). There, 27 per cent of the drivers had positive BAC's.

*California, Colorado, Delaware, Nevada, New Hampshire, New Jersey, Oregon, Washington, and Wisconsin.

In regard to other substances, incidence rate data are almost wholly lacking, as Joscelyn and others (1980) concluded. Their report did not include, however, a simultaneously appearing study on drugs in driver fatalities in the Province of Ontario during 1978 and 1979 (Warren et al., 1980). This study assessed over 90 drugs and found that the most frequent ones were as follows:

Alcohol	57%
Cannabinoids	12%
Salicylate	6%
Tranquilizer/ antidepressant	5%
Antihistamine	2%

The alcohol rate in this Canadian study was strikingly similar to American findings. This suggests that the other incidence rates may resemble American rates, but that cannot safely be assumed. In any case, it appears that alcohol is far more prevalent than any other single substance, but altogether other substances may be found in a considerable proportion of drivers killed. As to other drivers, in accidents or not, drug incidence rates are very much an open question.

Drug-linked crash risks. Widespread use does not in itself make a drug dangerous to driving; a highway safety problem arises only if drug usage significantly raises a driver's crash risk. While that risk has been definitely established in the case of alcohol, the jeopardies associated with other substances have been as little known as their incidence rates.

A useful way to estimate crash risk for any substance is to compare the proportion of accident drivers with that substance in their systems to the substance proportions for drivers on the road in the same circumstances as the accident drivers. The degree to which the substance is overrepresented among the accident drivers suggests how much the substance magnifies crash risks. (It may not be possible to separate the effects of the substance from the tendencies of the substance users, however.) That method has been applied to alcohol in several studies, beginning with Holcomb (1938) and including the

Grand Rapids study (Borkenstein et al., 1964) another by Farris et al., (1976) and others cited by Hurst (1974). The intensified crash risks associated with alcohol were shown in these studies.

Much more controversial have been indications of crash risks for other drugs. Joscelyn and others (1980) claimed that no studies, of large or small scale, have compared a representative sample of crash-involved drivers with a suitable control sample from the driving population. Yet some research reports claim or at least imply that drugs raise crash risks. Reeve (1979), for example, found a 15.9 per cent incidence of tetrahydrocannabinol (THC, the marijuana active ingredient) among arrested "impaired" drivers in California. The report states that the drivers were impaired by the marijuana, which presumably would mean the marijuana had increased crash risks. Joscelyn et al. (1980) pointed out the fallacy of such an inference, given the fact that 85 per cent of the THC-involved drivers also had alcohol in their blood. Since less than two per cent of all impaired drivers had only THC in their blood, this must be considered slim evidence for marijuana as a highway safety problem.

More substantial is the earlier-cited study by Warren and colleagues (1980), in which blood from fatally-injured Ontario drivers was analyzed. In that study, drivers with cannabinoids in their blood were judged culpable 1.7 times as much as drivers who were drugfree. That culpability effect was equal to that found for alcohol.

With respect to the tranquilizer-antidepressant group analyzed in the Ontario study, the crash "risk-factor" found for this group was the highest of the 90 drugs analyzed. There were 21 drivers in this group, twelve of whom had ingested diazepam. A portion of these had also ingested alcohol or some other drug. As they had in the analysis of cannabis culpability effects, Warren and colleagues used a mathematical method to estimate the risk factor associated with tranquilizers alone. They appropriately cautioned that with regard to any drug-involved group it is virtually impossible to separate the effects of drugs from the characteristics of the users.

A more extreme indication was in a British finding that tranquilizer users were five times more likely to become involved in an accident than a matched control group (Skegg, Richard, and Doll, 1979). There were only six "drivers" in the tranquilizer group, however, and three of them were riding a bicycle or moped. In addition, drug usage was identified by prescriptions rather than by blood tests.

Impairment effects of alcohol. While increased crash risk associated with a drug suggests that there is an impairment effect, the question remains as to the specific form of impairment that makes an accident more likely. Indicating these specific impairments is necessary for suggesting vehicle or roadway countermeasures that will reduce crash risk. It is difficult, however, to retrospectively determine in real accidents which aspects of driver performance were sufficiently degraded to cause or contribute to the crash.

Most previous efforts to determine impairment effects concentrated on alcohol, and studies have been of two main types:

(1) Experimental studies -- A large number of studies have used controlled conditions in laboratory or road testing sites to determine effects on voluntary subjects administered specific dosages of alcohol. Laboratory tests tend to concentrate on basic capabilities of the human organism, such as visual acuity and motor coordination. Vehicle simulators and road test facilities are used to create conditions closer to normal driving, while also assessing driving skills more directly. Such studies are valuable in suggesting which impairments may be causing "real life" accidents, but they cannot exactly reproduce the conditions under which crashes do occur. The driver's personal and social situation may be important conditions that cannot be duplicated.

(2) Epidemiological studies -- While there have been many large and small scale studies of actual crashes, hardly any have both positively identified alcohol-involved drivers and provided data on their accident-causing behaviors. A few studies link alcohol involvement with collision type, and from the latter, inferences may be made as to the driver errors that were involved. (A similar approach to identify pedestrian errors associated with alcohol was used in a study reported by Blomberg and associates (1979).)

Studies of both kinds were reviewed by Terhune and colleagues (1980), in order to determine the convergent indications of how and why alcohol increases a driver's risk of an accident. The main findings are summarized below.

From experimental studies*, alcohol is found to impair the following basic functions:

(1) Vision is affected in several ways. Dynamic visual acuity--the ability to perceive close but separated moving objects--seems impaired by BAC's as low as .03 per cent. At somewhat higher BAC's, darkness vision, particularly dark adaptation and brightness sensitivity, is degraded. The dynamic visual acuity effect could increase risks of crashes with other vehicles, while the darkness effects may increase likelihood of night crashes.

(2) Neuromuscular control functions, as may affect driving smoothness, cornering ability, and tracking, suffer in various ways from alcohol, particularly at intoxication levels. These impairments may pertain to crashes involving lane deviations and road departures.

(3) Attentiveness and alertness are seriously impaired by alcohol, and this may be the effect most detrimental to driving. High-demand driving situations (e.g. rush-hour traffic) may become very difficult for the motorist with decreased

*For detailed reviews, see Perrine (1974a), Browning and Wilde (1975), and Jones and Joscelyn (1978).

ability to divide attention among different traffic events while maintaining vehicle control and guidance. In low demand situations, on the other hand, the lack of external stimulation may further reduce an impaired driver's arousal level.

(4) Differential mood effects are suggested by some studies. On the one hand, alcohol acts as a depressant, with a sedative, numbing, fatiguing effect on the individual. On the other hand, alcohol is a disinhibitor, with an exhilarating effect on mood, and perhaps a facilitative effect on neurological activity. These "biphasic" effects have been emphasized by Barry (1974) and Perrine (1974), but it seems to be an open question as to whether the predominant factor in accidents is one or both effects. Barry (1974) suggests that the sedative effect could lead to driving off the road or into obstacles, while the exhilarating effect could increase speeding and risky maneuvers.

From the epidemiological studies, the following appear as the outstanding effects of alcohol impairment:

(1) Many studies have now shown the alcohol involved driver to be overrepresented in single-vehicle accidents. It is hard to say exactly what happens in these crashes, particularly as they are labelled differently in various studies. A Detroit-area study (Filkins, et al., 1970) found alcohol-impaired fatally injured drivers most frequently in "out-of-control" accidents, whereas Perchonok (1978) found police-designated drinking drivers overrepresented in "Class R" accidents*. The latter include road-departure and hit-parked-vehicle accidents, and Perchonok suggested passive drifting out of lane as the main explanation. The central issue is whether alcohol-involved single-driver crashes result mainly from speeding and recklessness or from passive lapse of control. This is the question of "biphasic effects" again. Perhaps both effects are salient, and perhaps both lead primarily to single-driver crashes. The issue remains unsettled.

*Perchonok's accidents were of mixed severity, mainly less severe crashes.

(2) Other collision types in which alcohol-impaired drivers are overrepresented are less easily distinguished. Perchonok's (1978) report found drinking drivers overrepresented in "stationary target ahead" crashes, but these seemed to be mainly another variation of hit-parked-vehicle collisions. Perchonok's data also showed a small overrepresentation of drinking-charged drivers in "parallel-opposite-lateral move" collisions, which would include head-on impacts. An even stronger representation of impaired drivers in head-on crashes was found in the Detroit area driver fatality study (Filkins et al., 1970). In FARS data, however, this effect was not so apparent (Terhune et al., 1980). Nevertheless, the balance of findings point to the head-on crash as one to which the alcohol-impaired driver is prone. Whether this reflects reckless passing or just another consequence of drifting out of lane is an open question.

One other collision type sometimes suspected of being an "alcohol type" is the rear-end collision (e.g. see Mortimer and Sturgis, 1980). In Perchonok's data, this was the second most common collision type among the alcohol-indicated drivers. But it was also common among the (apparently) sober drivers, so the proportion of drinking drivers in rear-end crashes was not unusually high. Nor were those proportions outstanding in the driver fatalities of the Filkins et al., (1970) study and the FARS data (Terhune et al., 1980). Yet in all three studies, alcohol-involved drivers were represented more in rear-end crashes than in intersecting path (angle) accidents. While assessments of crash risk (using exposure data) are needed to definitely settle this matter, it does appear that the alcohol-impaired driver may be somewhat more prone to rear-end crashes than the sober driver. This suggests an effect of inattentiveness and/or slowed reactions.

(3) Two other indications of possible impairment effects are in the data for nighttime and curve accidents. Many studies have found alcohol-involved drivers overrepresented in nighttime crashes. An interpretation that drinking drivers have a greater crash risk in darkness would be consistent with their visual difficulties found in experimental studies. However, as the

Grand Rapids study (Borkenstein et al., 1964) and others have found, there are more drinking drivers on the road at night. Zylman (1968), reanalyzing some of the Grand Rapids data, did not see evidence that crash risk of alcohol-involved drivers (relative to sober drivers) is actually increased at night. Therefore, it cannot be definitely said that alcohol gives drivers special difficulties in coping with darkness.

While the majority of both alcohol and nonalcohol accidents occur on straight road sections, both the Filkins et al.(1970) and Perchonok (1978) studies found a greater proportion of alcohol-involved drivers in accidents on curves than on straight road sections. In breakdowns by collision type and horizontal road alignment, Perchonok's data show the curve accidents to be mainly the lane/road departure type. Whether these crashes result from inattentiveness or excessive speeds cannot be established. It does appear, however, that curves are especially hazardous to the drinking driver.

(4) In what may have been the only study attempting to identify driver failures in alcohol-involved crashes, Perchonok (1978) examined "critical reasons." These are the most immediate causes* of accidents, and they include vehicle failures, driver breakdowns (e.g. blackouts, falling asleep) and a variety of driving failures, such as information failures and control failures. Surprisingly, the study did not reveal the "drinking" and "normal" drivers to differ much in the critical reasons. A large majority in both groups exhibited "tracking errors," defined as "failure to maintain the intended vehicle path." The drinking drivers were somewhat more frequently coded as losing control of their vehicles and as having "driver breakdown."

(5) Speeding is often mentioned as an effect of alcohol impairment, but this conclusion seems to rest exclusively on after-the-fact judgements in accident studies (Ernst and Ernst, 1968; Filkins et al., 1970; Fingerman, 1977; Perchonok, 1978). There are problems with such data, in that: (a) they may pertain only to accident drivers; (b) vehicle speeds

*As judged by coders.

are retrospective estimates only; and (c) the distinction between travel speed and impact speed is not made. Of course, in cases where the judged impact speed is beyond the legal limit, a conclusion of "unsafe speed" may be made. However, the higher impact speeds of the impaired driver could reflect a lack of timely braking rather than speeding. The proposition that drinking drivers speed is called into question by one study that used radar to measure vehicle speed and breath analyzers to determine driver BAC's (Damkot et al., 1977). In this early-morning study on Vermont rural roads, over half the drivers had positive BAC's. There were, however, essentially no statistically significant relationships between BAC and measured vehicle speed.

The speeding question is an important one and, as was noted earlier, it is particularly relevant to understanding the distinct overrepresentation of impaired drivers in road departure crashes. Perhaps the answer to this perplexing issue is a combination of the following:

(a) On the average, alcohol impaired drivers are not more inclined to speed than sober ones;

(b) Some drivers are inclined to speed under the influence of alcohol, while others drive too slowly (Harris, 1980);

(c) When an alcohol-impaired driver speeds, he is less able to handle his vehicle safely than a sober driver who speeds;

(d) When a crash is impending, an impaired driver is less successful in slowing his vehicle.

In summary, both experimental and epidemiological studies converge upon driver inattention and reduced alertness as alcohol impairments which play a key role in drinking driver accidents. Impaired drivers commonly run off the road (particularly on curves), or deviate to the right to hit a parked vehicle, or deviate to the left to hit an oncoming vehicle. They may also tend to run into the rear ends of other vehicles; although available data are less clear in this respect, the tendency is consistent with an effect of inattention and reduced alertness. Other alcohol impairments that have been suggested in the literature are exhilaratory effects that lead to speeding and reckless driving, and impaired visual perception in darkness. Crash studies have not as yet established whether these are significant dangers of alcohol, but speed does seem a relevant factor in alcohol crashes.

Impairment effects of other drugs. While a few epidemiological studies have indicated drug incidence and one examined culpability levels associated with drugs, apparently none has examined the ways that drug impairment effects contributed to crashes. Consequently, indications of drug impairments that may make driving dangerous are limited to experimental studies. The literature was reviewed by Joscelyn and colleagues (1980) , who noted the several problems that make it difficult to extrapolate to real life driving situations. Not only is there the question of how performance of experimental tasks relates to driving performance under actual traffic conditions, but there are reasons to doubt that test subjects represent the real users of drugs and the ways they use them. Consequently, the fact that drug impairment effects are commonly found in experiments gives no proof of ways in which crashes will be caused.

Some of the measured impairment effects that may increase crash risks are mentioned briefly here.*

(1) Marijuana research indicates that marijuana can impair tracking ability and perceptual functions. For example, time sense, reaction time, auditory signal perception, and glare recovery may be altered (Joscelyn et al., 1980). While performances on simple tasks may be unaffected until

*Indications here were obtained from the reviews of others, and they are provided only to convey a general picture.

higher dosages, complex processes such as perception, attention, and information processing are impaired by doses equivalent to one or two cigarettes (Gilman et al., 1980).

(2) Benzodiazepines ("tranquilizers" such as diazepam*) have been found to impair performance in many ways, such as in tests of vigilance, choice reaction time, and motor coordination (Joscelyn et al., 1980). These need not be severe impairments, however. In a review by Howat and Mortimer (1978), it was concluded that "Considerable research has shown that tranquilizers often have no significant effects on performance and skills related to driving" (p. 567). This group has not the general depressant effects of alcohol (Gilman et al., 1980). From these reviews, tranquilizers taken alone would not seem to have the dangerous implications for traffic safety that alcohol has. There seems to be a consensus, however, that dangerous effects may result from the combination of tranquilizers and alcohol.

(3) Barbiturates and other nonbenzodiazepine sedative and hypnotic drugs have been found to impair thinking, motor coordination, alertness, and to decrease oculomotor functions. These drugs have been judged, in certain dosages, to impair driving performance (Joscelyn et al., 1980).

(4) Stimulants such as amphetamine and cocaine may actually improve driving performance, especially in combatting fatigue and maintaining alertness. However, impairment could arise quickly when the effects subside, and withdrawal symptoms also may have dangerous consequences (Joscelyn et al., 1980).

Other substances have been examined in experimental studies, and they too have demonstrated effects that could endanger driving. None of the experimental research can demonstrate, it is well to remember, that a substance is a highway safety problem.

* One benzodiazepine, flurazepam, is used as a sleeping pill rather than as a tranquilizer.

Perchonok's study as a foundation. Several of the hypotheses tested in this project stem directly from the Perchonok (1978) study discussed previously. That study was a valuable milestone in its further clarification of alcohol collision types, in revealing some of the special circumstances of alcohol accidents, and in its attempts to reveal specific alcohol behavioral impairments. The study had the advantage of a large sample size, comprising 7421 Western New York accidents of mixed severity. Because BAC data were available in only a few cases, however, the judgments of the reporting police officers were relied upon to identify alcohol-involved drivers. "Had been drinking" notations and "Driving While Intoxicated" citations were used as proxy indicators of low and high BAC levels in the data analysis. Drugs beside alcohol were not identified.

One of the more intriguing but controversial results of the Perchonok study was its indicated differences between the "had been drinking" and "intoxicated" drivers. In several respects, the intoxicated drivers appeared more like the "sober" drivers than did the "had been drinking" drivers. Specifically, the similarities were in proportions of road departure and rear end crashes, driver control loss, high speed and reckless driving citations, and in two-lane road accidents. From such results, Perchonok suggested that modestly impaired drivers tend to drive recklessly, while intoxicated drivers tend to recognize their impairment and drive more cautiously. This inference exactly opposed that of Zylman (1968). From selected data of the Grand Rapids study, he suggested that the low-BAC driver may drive extra-cautiously. It will be useful to see what light the present study can shed on the issue.

Specific Questions/Hypotheses This Study Addresses

The formal objectives listed earlier and the issues arising from previous studies were integrated to generate specific questions this project would address. These are as follows.

(1) What were the incidence rates of alcohol and other substances found in the blood of injured drivers taken to a hospital?

This question exactly reflects the study's first objective. To our knowledge, the study provides the first comprehensive assessment of drugs in the systems of injured drivers. In addition, the study employs the recently developed capability (Foltz & Fentiman, 1980) for quantifying the amounts of THC in blood samples.

(2) Which drivers, among the drugfree and drug-involved, had the highest accident culpability rates?

In regard to any drug, the question most fundamental to highway safety is whether it sufficiently impairs drivers to raise crash risks. Ideally, the relative crash risk for a substance is determined by comparing its incidence among drivers on the road* with its incidence among drivers in accidents. To best isolate the effects of the drug, the comparison should be between driver groups similar on dimensions such as age and sex, and who are exposed to circumstances similar in time, place, and ambient conditions. In lieu of this more ideal study design, an alternate to relative crash risks uses judgments of driver culpability (or responsibility) for crashes. Elevated crash risks are suggested for a substance-involved group of drivers when their culpability rate significantly exceeds that for a comparable drugfree driver group. In this study, culpability rates were determined for all drug groups with sufficient numbers of cases, and these were compared with the rates for drivers free of any of the tested drugs.

*In other words, drivers not in accidents.

(3) Do the collision types of alcohol and other drug-involved drivers differ from those of sober drivers?

As shown in the Background section, collision types associated with a substance suggest the kind of impairment created by that substance. To be sure, a collision type does not reveal exactly what a driver did wrong, but it permits an inference based on crash data which are fairly objective and confirmable. As with culpability rates, the crashes of a substance-involved driver group are compared with crashes of a drugfree group.

(4) Assuming that this study finds, as have others, that road departure crashes are especially prominent among the alcohol-involved drivers, are those due more to passive drifting off the road or to active loss of vehicle control? Does the type of problem differ between low-BAC and high-BAC drivers?

In the Background section it was noted that other investigators have posited two rather different reactions to alcohol--the numbed, sedated state and the exhilarated, disinhibited state. Some have suggested that the first effect may be common at high BAC's, while the second would more likely occur at low BAC's. The first could cause road departure crashes through reduced alertness and "lapse" of control, while the second could result in road departure from speeding and active loss of control. Evidence for each of these road departure situations is examined in this study.

(5) Do the rear-end accidents of impaired drivers differ from the crashes of sober ones?

The Background section noted the ambiguity of evidence as to whether alcohol-impaired drivers are any more prone to rear-end accidents than are sober drivers. This may be clarified by looking at more specific kinds of rear-end accidents: (a) the "tailgating" accident, where a decelerating vehicle is impacted by a closely following one; (b) the overtaking accident, where a vehicle catches up with and strikes a slower vehicle, and (c) the hit-stopped-vehicle accident, where a momentarily stopped vehicle (e.g. at a traffic signal) is hit from behind. Each of these in order would seem to result from an increasing degree of inattentiveness (and underarousal perhaps); distinguishing among them may clarify the role of impairment from alcohol or other substances.

(6) Do the alcohol and other driver groups differ in the circumstances of their accidents?

Past research has indicated that the crashes of alcohol-impaired drivers tend to occur under particular sets of circumstances (Fell, 1977; Perchonok, 1978; Jones and Joscelyn, 1980; Terhune et al., 1980). As a way of determining whether alcohol crashes in this study represent a typical or deviant sample, circumstance variables are examined here also. They include driver age and sex, urban-rural location, road curvature, road type, road surface condition, time of day, lighting, vehicle type, and land use. These were examined also for the crashes of other drug-involved drivers, in comparison with the drugfree drivers.

(7) What are the major "alcohol accident types," defined as those combinations of collision type and crash circumstance variables that have the highest proportion of drinking drivers?

In developing countermeasures for pedestrian accidents, it was found useful to identify "accident types" describing the main circumstances and sequences of events of those accidents (Snyder & Knoblauch, 1971). Similarly, countermeasure development for the drinking-driver problem may be aided by identifying "alcohol accident types." By determining the combination of crash circumstances and collision type that have the highest proportions of alcohol-involved drivers, the "targets" for countermeasures may be more sharply delineated. The analysis here readily follows from the analyses for questions 3 and 6.

(8) Do the collision types of alcohol-impaired drivers differ in their circumstances from the collision types of sober (drugfree) drivers?

This question also is a kind of extension of questions 3 and 6, but it can lead to special insights into the ways that the problems of drinking drivers differ from those of sober ones. It first examines the collision types and circumstances of sober driver crashes as a way of determining which variables, such as driver age and time of day, are linked to collision types. We may ask, for example, are road departures most likely to be found at nighttime and when road surfaces are slick? By examining the data for drugfree drivers, we learn about crash hazards apart from the influence of alcohol or any other drug. By then repeating the analyses for alcohol-involved drivers, we shall see whether results differ from the drugfree ones. If they do, the nature of alcohol impairment may be clarified. If they do not, an implication may be that some of the problems of drinking drivers are their greater exposure to certain hazards. This may be an important part of the drinking-driver accident story.

(9) How accurate are the police, and hospital personnel, in identifying impaired drivers?

Although this question is not a basic concern of the study, the data provide a unique opportunity to evaluate the success of police in detecting impaired drivers. The blood test results will show conclusively the alcohol and drug statuses of the drivers, and these may be compared with police accident reports of alcohol involvement. One value of this analysis is to show whether improvements are needed in police detection methods, so as to strengthen drunk-driver law enforcement. Another is to judge whether police reports provide valid indications of impaired drivers for research purposes.

In addition to revealing accuracy of the police, the study will also examine the success of hospital emergency department personnel in judging a driver's impairment. This too could be an aid to research where BAC tests cannot be administered.

Summary

In summary, the study reported here addresses several important questions on the role of alcohol and other drugs in highway safety. Previous research has revealed much on the involvement of alcohol in accidents, but important questions remained as to the most relevant impairment effects. Comparison of the crashes of alcohol-involved and drugfree drivers are used in this study to address some of the questions, with an eye to suggesting roadway and vehicle countermeasures. In addition, "alcohol accident types" are determined for possible application to deterrence countermeasures. Regarding marijuana and other drugs, the study seeks mainly to suggest whether any constitute a significant highway safety problem. While this study is a limited one, it can provide further evidence as to the potential seriousness of the drug problem.

2. STUDY DESIGN

Overview

To address the specific questions of this study, the overall strategy was (1) to collect and analyze blood samples from injured drivers; (2) to determine the incidence rates of alcohol and other drugs in those samples; and (3) to examine relationships between the blood contents and variables describing the drivers' accidents. Various aspects of this strategy will be discussed in turn.*

Injured drivers. After considering fatally injured drivers, nonfatal injured drivers, and drivers in property damage accidents, injured drivers were selected to provide a sample with the best balance of various factors. Injured drivers comprise a substantial portion of all accident drivers, which is not true of the fatally injured. In addition, surviving drivers can be questioned for details about the circumstances and causes of their accidents, matters central to this study. Obtaining a blood sample would be facilitated by focusing upon injured drivers appearing at a hospital for treatment or examination. And finally, injured drivers constitute an intrinsically important group because the severity of their accidents not only imposes suffering on themselves and others, but their accidents incur significant costs to society.

It may be noted that the third consideration above narrows the driver sample slightly to include drivers whose injuries are serious enough to send them to a hospital.

*The original proposal and general study plan were the work of Kenneth Perchonok, now of the Institute for Research, State College, Pennsylvania.

Drugs studied. During workshops held by the National Highway Traffic Safety Administration and the National Institute on Drug Abuse (Joscelyn and Donelson, 1980), a list of substances considered to be a risk to highway safety was devised. These were evaluated by the workshop members on "exposure" (including "characteristics of users and characteristics of use") and on "effects" (including "pharmacodynamics, pharmakinetics, and behavioral effects"). By making these judgments on two rating scales, and multiplying the scores together, an overall rank order of the judged hazard to highway safety of the drugs was produced. A few of the substances on the original list were excluded from analyses in this study because analysis costs would be too high and/or the significance of the drug was considered minor. A list of the substances and substance groups for which analysis was made is presented in Table 1.

Analytic strategy. Beyond the determination of incidence rates, the analyses address the most fundamental question of this study: Does the presence of one or more particular drugs in a driver's blood play a role in accident causation? Expanding this somewhat, does the drug, alone or in combination with others, increase a driver's likelihood of having an accident and/or does it influence the kind of accident the driver has or the circumstances in which he has it?

To address these fundamental questions, the primary analytic strategy was to compare accident drivers with a particular substance (or substance combination) in their blood with accident drivers whose blood was drugfree.* Differences in the accidents of those groups were used to infer effects of the drugs. The rationale was that driving problems found significantly more frequently among accident drivers who had ingested a substance than among those free of drugs may be partially attributable to that substance.

In the analyses, the drug-involved and drugfree drivers are compared on two dependent variables as follows:

*More accurately, the "drugfree" drivers are those whose blood (a) at the time it was drawn, (b) was free of drugs tested for (c) as far as can be determined with the chemical analyses employed.

TABLE 1. - DRUGS STUDIED

(In rank order of significance as judged in NHTSA-NIDA workshops.)

Drug or Drug Grouping (Trade or Other Names)	Examples
1. ethanol	(alcoholic beverages)
2. diazepam [Valium]	
3. cannabis	(e.g. marijuana, hashish, cannabinoids)
4. codeine	
5. flurazepam [Dalmane]	
6. d-propoxyphene [Darvon, Darvon-N, Darvon with A.P.C., etc.]	
7. antihypertensive agents	(e.g. hydralazine, methydopa)
8. oxycodone [Percodan]	
9. barbiturates	(secobarbital, pentobarbital, amobarbital inclusive)
10. chlordiazepoxide [Librium]	
11. over-the-counter antihistamines	(e.g. diphenhydramine, chlorpheriramine methapyriline, doxylamine)
12. pentazocine [Talwin]	
13. methadone	
14. meperidine	
15. hydromorphone	
16. antidepressants	(e.g. amitriptyline, nortriptyline, imipramine, desipramine, doxepin)
17. anticholinergics	(e.g. atropine, scopolamine, methantheline [Banthine])
18. antipsychotics	(e.g. chlorpromazine, prochlorperazine, chlorprothixene)
19. hallucinogens	(e.g. mescaline, psilocybin, MDA, STP)
20. phencyclidine [PCP]	
21. caffeine	
22. glutethimide [Doriden]	

(Continued)

TABLE 1. - (Continued)

Drug or Drug Grouping (Trade or Other Names)	Examples
23. methaqualone [Parest, Quaalude, Sopor, etc.]	
24. anesthetics for out patient therapy	(e.g., thiopental, methohexital, halothane, lidocaine, etidocaine, flunitrazepam, alphadione)
25. other barbiturates	(e.g. butabarbital, talbutal, mephobarbital, metharbital)
26. heroin	
27. prescription antihistamines	(e.g. diphenhydramine, pyrilamine, chlorpheniramine, pheniramine)
28. amphetamines	(e.g. dextroamaphetamine, methamphetamine, phenmetrazine)
29. ethchlorvynol [Placidyl]	
30. chloral hydrate [Noctec, Somnos, etc.]	
31. other anti-anxiety drugs	(e.g. oxazepam, meprobamate, lorazepam)
32. anticonvulsants	(phenobarbital, phenytoin [diphenylhydantoin], primidone, carbamazepine, ethosuximide, trimethadoine)
33. cocaine	

Excluded drugs (from original list): LSD; methylphenidate; antidiabetic agents; nicotine; carbon monoxide; haloperidol; phenelzine; digoxin and digitoxin; Lithium; propalolol.

(a) Culpability--the judged degree of responsibility of each driver for the accident in which he was involved. Analyses on this variable are used in absence of data for determining the relative crash risk associated with each drug or drug group.

(b) Collision type-- the crash configuration defined by such things as number of vehicles involved, their initial locations and paths, and their movements during the crash sequence. Comparing the drug-involved and drugfree drivers on this variable suggests the kinds of driving problems to which the drug-impaired may be more prone.

The measurement of these variables will be described later in the report.

Limitations. As far as drug incidence rates are concerned, it must be realized that the motorist sample in this study is limited to accident drivers, who appeared at a particular hospital (to be described shortly) and for whom a useable blood sample was obtained. It is hard to say just which driver population this sample "represents," and for this reason, the study should be considered exploratory. The study will suggest the drug incidence rates that may be found among injured drivers generally, but a more accurate picture of those incidence rates must await a more representative national sample. Until and unless such a sample is obtained, incidence rates of this study should be considered along with incidence rates in other studies. To the extent that different studies in different locations produce similar results, general incidence rates may more confidently be inferred. It is to be expected, however, that substantial differences may be found among drivers (a) not in crashes, (b) in property-damage only crashes, (c) in injury crashes, and (d) in fatal crashes. If a drug increases crash risks, it will be found more frequently among drivers in crashes; if the drug increases crash severity, it will be found more among drivers in severe crashes.

As to the <u>effects</u> of the drugs on highway crashes, it should be recognized that there are definite limitations on learning about the causes of crashes by examining only crash-involved drivers. The proportions (of collision types, driving errors, or whatever) indicate <u>contingent</u> probabilities, not absolute ones. For example, proportions of collision types among drivers in accidents indicate the probability of that accident type <u>if</u> the driver has an accident. We can compare such contingent probabilities across drinker and nondrinker groups, but without exposure data we can infer little about relative probabilities. For example, although we may find nearly equal proportions of the collisions of drinking and nondrinking drivers to be the head-on type, there is no basis for inferring whether drinking drivers are equally, more, or less prone to head-on accidents than are nondrinking drivers. This problem tends to be particularly aggravated by the fact that lane/road departures constitute an unusually large proportion of drinking-driver accidents, which necessarily reduces their proportions of all other accident types. Yet even the proportionately least frequent collision type for intoxicated drivers may have a higher relative risk of occurring with an intoxicated driver than with a drugfree driver. Determining the relative risks would require comparison of crash drivers with noncrash drivers whose blood drug content is known.

A caveat should also be noted with regard to the possibility of wrong inferences resulting from confounded variables. Past research has already shown that drinking drivers tend to be on the road at different times and places than sober drivers. There are also average differences in the kinds of people who drive while impaired and those who do not. These kinds of differences may also be expected with regard to drug usage and drug users. Differences among the accidents of any drug-involved drivers and drugfree ones may be due to the variables correlated with drug involvement and not to drug impairment effects. For example, anything unusual about the crashes of drivers with medically prescribed phenobarbital may be due more to the problem for which the phenobarbital was prescribed than to any problem created by the phenobarbital. For another example, marijuana users may have crashes atypical in certain respects because marijuana users themselves are atypical of all drivers. To a certain extent, the problems of confounding variables may be controlled in the data analyses, but that may not always be possible.

While these limitations exist, it should be remembered that we presently know little about whether and how drugs other than alcohol are causing accidents; even our knowledge of how alcohol affects crashes is modest. Against that background, this study can provide valuable clues as to the significance of drugs to the highway safety picture.

Site Selection

The original plan was to collect data in the general area of Erie County, New York (where Calspan Field Services, Inc. is located). Consequently, hospitals in the Buffalo area which accounted for most of the emergency care were visited to solicit their participation in the study. All of the private hospitals refused on grounds related to liability for drawing blood for non-medical purposes. However, interest in participating in the study was shown by a county-owned hospital.

Negotiations were entered with the county hospital to work out a sampling procedure acceptable to all parties. Discussions involved the hospital's Human Subjects Committee, the hospital Medical Director's Office, the County Attorney, Calspan attorneys, and the State Attorney General. Central issues were the legal constraints and responsibilities incurred in obtaining blood specimens versus the requirements for a valid and useful research project. From the standpoint of obtaining an unbiased sample of drivers, it was considered necessary to obtain blood specimens from all or nearly all injured drivers taken to the hospital's emergency department. But since blood samples were not routinely drawn on drivers, their informed consent was a requirement to obtain a specimen for research purposes. The research team feared that limiting the study to consenting drivers would introduce several biases, including an expected high refusal rate from alcohol and drug-involved drivers. Ultimately, failure to reach agreement on some method of obtaining blood samples led to abandonment of discussions with the county hospital. Prospects for a cooperating hospital outside of Erie County were then investigated.

Contacts with Dr. John D. States of the Rochester General Hospital (N.Y.) resulted in an agreement that that hospital would participate in the study. Rochester General Hospital is an affiliate of the University of Rochester, which supports an authorized New York State Accident Investigation Unit under the direction of Dr. States. The hospital receives most of its patient clientele from Monroe County and the hospital's Emergency Department is the busiest in the county, having approximately 54,000 patient visits per year. A wider geographic area is served by this hospital than by the county's other hospitals. Monroe County encompasses large areas of rural-agricultural land, suburbs, and the City of Rochester, a major industrial and commercial center. The county is traversed by a wide variety of road types, including Interstate Highways 90 (the New York State Thruway) and 490. The wide spectrum of road types and land use was considered an asset for this accident study.

The Sample

In order to provide data on incidence rates, it was desired to obtain as complete a representation as possible of <u>all</u> injured drivers appearing at the Emergency Department of Rochester General Hospital. The only limitations were:

(a) The driver's accident must have happened within Monroe County (to facilitate accident investigation and the gathering of police reports);

(b) the accident had to occur within four hours of the driver's arrival at the hospital (to minimize false negatives due to elimination of substances from the driver's blood).

(c) the driver was operating a motor vehicle (no bicycles), but snowmobiles were excluded;

(d) the accident must have occurred on a road or in a parking lot (thus excluding off-road accidents such as with "dirt bikes" or all-terrain vehicles)

Seeking a comprehensive sample was an ambitious undertaking, for special efforts would be necessary to include minors, unconscious drivers, and incoherent drivers. Since blood samples would be obtained and analyzed only with written consent, the following special measures were adopted.

(a) In the case of minors, the written consent of the minor and parent was needed.

(b) With the unconscious or incoherent drivers, a relative's consent was sought to draw the blood sample, which would be analyzed only if the patient gave written consent when he was sufficiently recovered. If the patient refused to give that consent, the blood sample was destroyed without analysis. As might be expected, there were cases where no relative was available to provide consent to draw a blood sample, in which case the driver was lost to the study.

No eligibility restrictions were made with respect to time. Drivers were to be sampled during 24 hours each day and for seven days a week continuously until the desired sample size was met.

Sample size. In C.F.S.I.'s* original proposal and in subsequent research plans and memos, a sample size of around 700 drivers was recommended. This size was expected to provide adequate statistical power to detect differences between the anticipated number of alcohol-indicated drivers and their drugfree counterparts. A 700-driver sample was not essential, however, if the data were to be used primarily to estimate drug incidence rates. With 500 drivers, for example, confidence limits of $\pm$ 2-4% could be provided, and little would be gained by adding 200 more drivers. Since the drug incidence

*Calspan Field Services, Inc.

rates became the project's top priority objective for NHTSA, and considering problems in getting driver consent (to be discussed later), and considering the data collection costs, the decision was reached within NHTSA to obtain a study sample of 500 drivers.

Accident Data

To answer study questions in which the driver's blood content is linked to accident details, the latter were obtained from various sources. Since no one source is uniformly reliable for all crash details, accident investigation commonly uses several sources, which often overlap in the details they provide.

Because of the uncertainties about the proportion of drivers who would permit blood samples to be taken, particularly among the alcohol and drug involved, the project was initially run on a test basis. This Pilot Phase also permitted an examination of procedures and operating costs. During the Pilot Phase, the accident investigations included accident scene examinations, crash vehicle examinations and driver interviews, as well as police accident reports. This investigative scope proved too costly, however, in part because of the extensive travel time required by the scene investigators in traveling between Buffalo and Rochester. Consequently, the study design was revised to include only police reports and driver queries as the sources for the accident data. This resulted in the elimination of some variables, such as departure angles in road departure crashes.

3. THE DATA COLLECTION SYSTEM*

Although this study was exploratory, it required a fairly complex data collection system. This was especially true during the pilot study phase, when accident scene investigations and crash vehicle examinations were conducted in addition to the collection of blood samples, police accident reports, and driver interviews.

Besides the collection of data, important functions of the data collection system were to:

(a) Identify eligible drivers and secure the written consents necessary to draw and analyze their blood samples;

(b) Review all police files in Monroe County to detect drivers allegedly taken or sent to Rochester General Hospital (RGH), and confirm their arrival using the hospital medical records;

(c) Separate the blood samples into whole blood and plasma samples, properly pack them, and ship to the analytic laboratory;

(d) Produce records of all system operations to facilitate system monitoring and the identification of system malfunctions;

(e) Bring together all system data and records at CFSI to produce case files;

(f) Insure that no driver identifying records remain anywhere in the system.

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*The more general reader may prefer to skip this chapter, which gives procedural details.

Figure 1 shows the main components of the data collection system. The functions of these components were as follows.

(1) RGH Emergency Department -- This component detected eligible drivers, sought and obtained consent for blood samples. and drew the blood samples.

(2) RGH Chemistry Laboratory -- Here the blood samples were separated into whole blood and plasma, each of which was placed in glass containers and labelled with identifying numbers. The containers were then specially packaged and sent for analysis to the Center for Human Toxicology at the University of Utah.

(3) University of Rochester Accident Investigation Unit (URAIU) -- Under the direction of Dr. John D. States, this component initiated case files, obtained all police accident reports, and examined case vehicles (during the pilot phase). In addition, its members requested written consent for the analysis of blood samples obtained from unconscious and incoherent drivers on the basis of a relative's consent.

(4) Calspan Field Services, Inc. -- CFSI was responsible for designing and monitoring the performance of the entire data collection system, in consultation with URAIU, the RGH staff, and the Center for Human Toxicology. In addition, CFSI accident investigators examined the accident scenes (during the project's pilot phase) and interviewed drivers in the accidents.

To facilitate effective operation of all system components, an operating manual or protocol was prepared for each person-role within the system. These manuals and protocols described in step-by-step sequence how the project tasks were to be achieved. In many instances tasks assigned to a person-role included checks and corrections on the outputs of other role incumbents. Not every detail of these operations will be provided here, but in the sections below the key details of the data collection sub-systems are discussed.

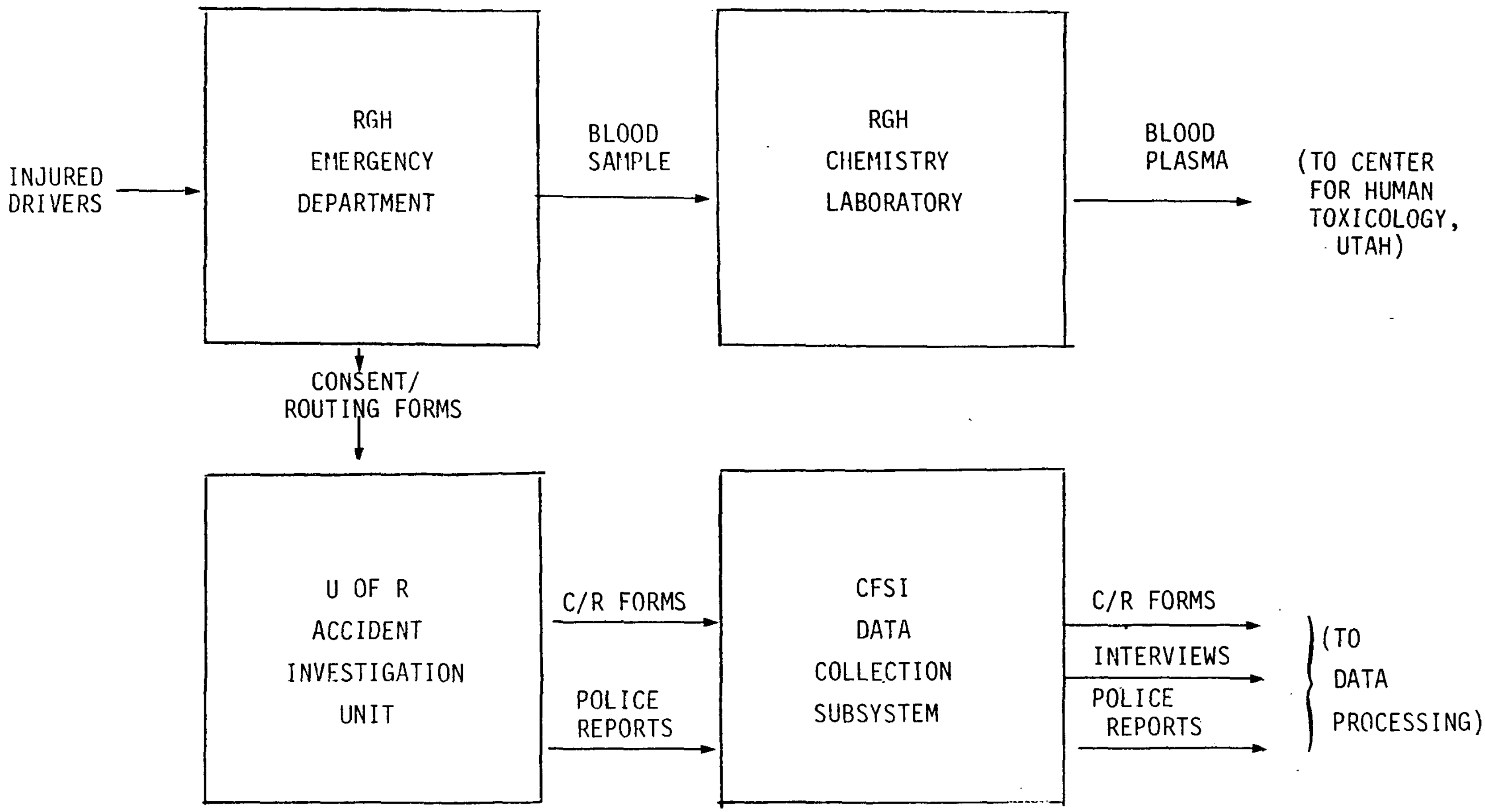


FIGURE 1. - MAIN COMPONENTS OF THE DATA COLLECTION SYSTEM

Because data collection was complex during the Pilot Phase, that period involved a continuous evaluation of costs in relation to data needs, all while attempting to maintain quality control in the data gathering. A few revisions of the system had to be made even during the Pilot Phase. Upon completion of that phase, some data collection was interrupted while the details of a modified project design were being worked out between CFSI and NHTSA. These events affected the amount and nature of data available for analysis, so they are noted in the methodological descriptions to follow.

RGH Emergency Department

The Emergency Department was crucial as the "gatekeeper" for a driver's entry into the study. For that to happen, the following steps were necessary (see Figure 2).

(1) The driver is detected as eligible for the study by someone on the Emergency Department staff, usually an intake secretary. This meant the staff members had to identify the presenting patient as a driver in a motor vehicle accident which happened in Monroe County within the previous four hours. The staff member would then initiate a Consent/Routing Form (see Appendix A), which would accompany the drivers and signal to other staff members that the driver was eligible for the study.

(2) The driver is asked to provide a blood sample. The first nurse to attend to the driver's needs usually was the one to request consent to draw a special blood sample. Suggested wording for the request was the following:

> As part of the effort to reduce accidents, we are doing a study on their causes. We are asking all injured drivers for permission to draw a small sample of their blood. Please read this consent form and sign it, if you will.

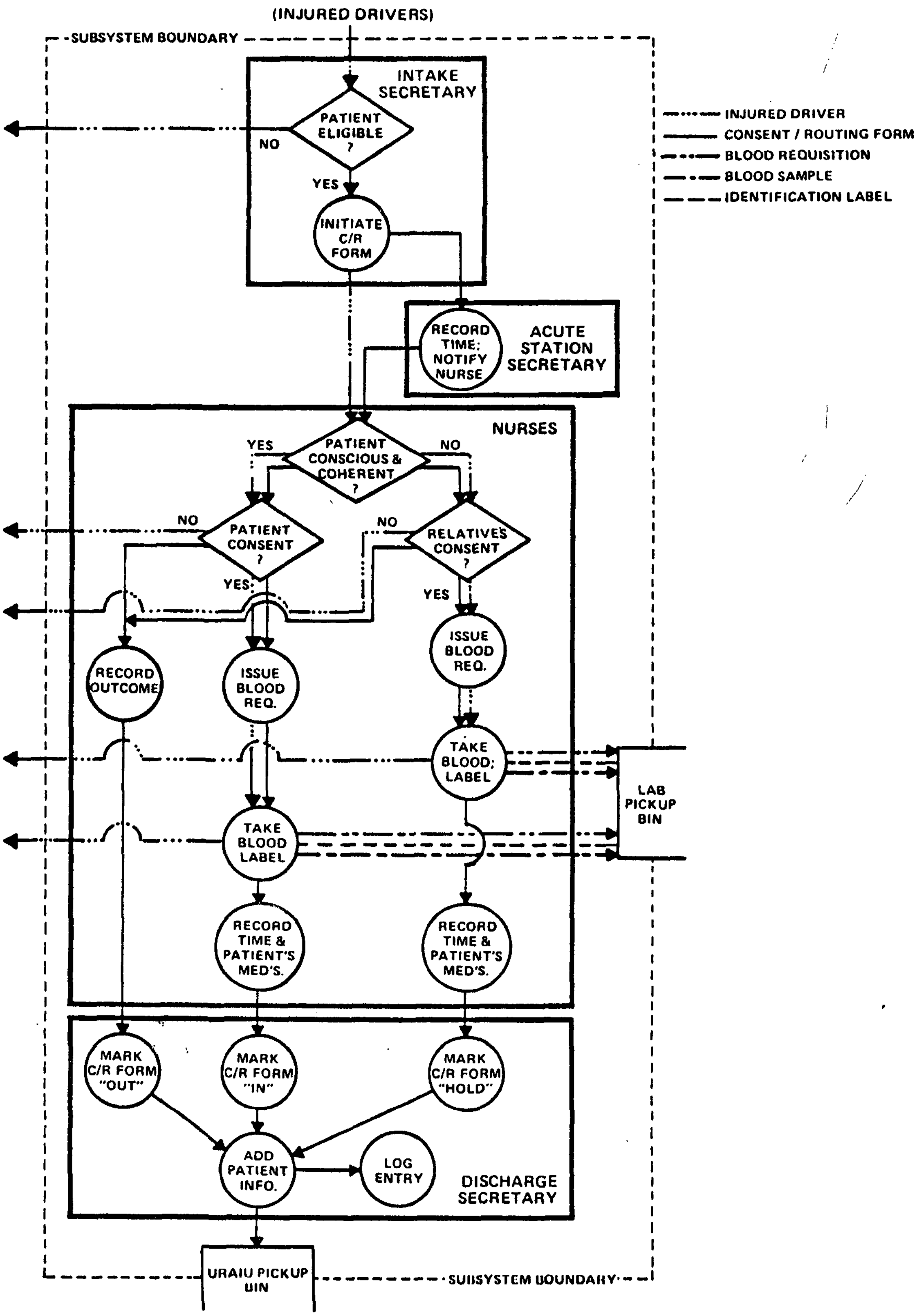


Figure 2 EMERGENCY DEPARTMENT COMPONENT OF DATA COLLECTION SYSTEM

At this point the driver was shown the Consent/Routing Form, which indicated that the driver's anonymity would be preserved, as per New York State law.* The nurses were permitted to vary the wording of their request to avoid stiltedness, but in any case they were to convey the same ideas. Drivers could be encouraged to permit the blood sample, and occasionally a physician might ask a reluctant driver a second time. The staff was provided written information about the study to help them answer any questions by the drivers.

For unconscious or incoherent drivers, an attempt was made to secure a relative's consent to draw a blood sample, which would not be analyzed until the driver's consent signature was also obtained. If a relative was not present, hospital procedures allowed for a relative's permission to be obtained by phone. This would involve a second medical staff member, who would witness the receipt of consent.

If the driver was a minor, both the driver's and a parent's signature were needed to draw and analyze the blood.

(3) The blood sample is drawn. If the driver had consented, a 15 cc sample of his blood was drawn in special Venoject tubes, which contained a preservative.

(4) The sample is labelled with an identifying number and sent to the hospital Chemistry Laboratory. A special project label was used for this purpose. The identifying number was independent of any in the hospital's record system.

The Consent/Routing Form also provided a space to record a driver's reason for refusing a blood sample. The most common reason expressed was an aversion to hypodermic syringes ("I don't like needles"). Other reasons given were being upset or ill. If a blood sample was obtained, the time of drawing

*New York State law (Ch. 742, 1972) protects the confidentiality of data collected by its "approved accident investigation units," which include Calspan and the University of Rochester unit.

and any drugs administered prior to the sample were recorded. The staff members were also asked to indicate any behavioral evidence of intoxication.

(5) Release the Consent/Routing Form. After each eligible driver was processed, his status was recorded on the Consent/Routing Form. The status would be one of the following:

(a) "In" - The driver had provided a blood sample.

(b) "Out" - A blood sample had not been drawn.

(c) "Hold" - The driver was unconscious or incoherent, and a blood sample was drawn with a relative's consent; when conscious and coherent, the driver's written consent was to be requested. (Later this status would change to "in" or "out" according to the driver's response.)

With the driver's status as the final entry, the Consent/Routing Form was then released from the Emergency Department, to be picked up by the University of Rochester Accident Investigation Unit.

While further details of the Emergency Department operations are relevant to describe the driver sampling process, they are presented at the end of this chapter to maintain the continuity of the presentation here.

RGH Chemistry Laboratory

Since the blood analyses were to be performed elsewhere, the Chemistry Laboratory at RGH served the function of preparing the samples for shipping and storing them until the next shipment was made. (See Figure 3) Each blood sample required the extraction of plasma from a three cc subsample. (Later, the tests for cannabis would be made on the plasma.) The plasma and the remaining twelve cc's of whole blood were placed in separate containers,

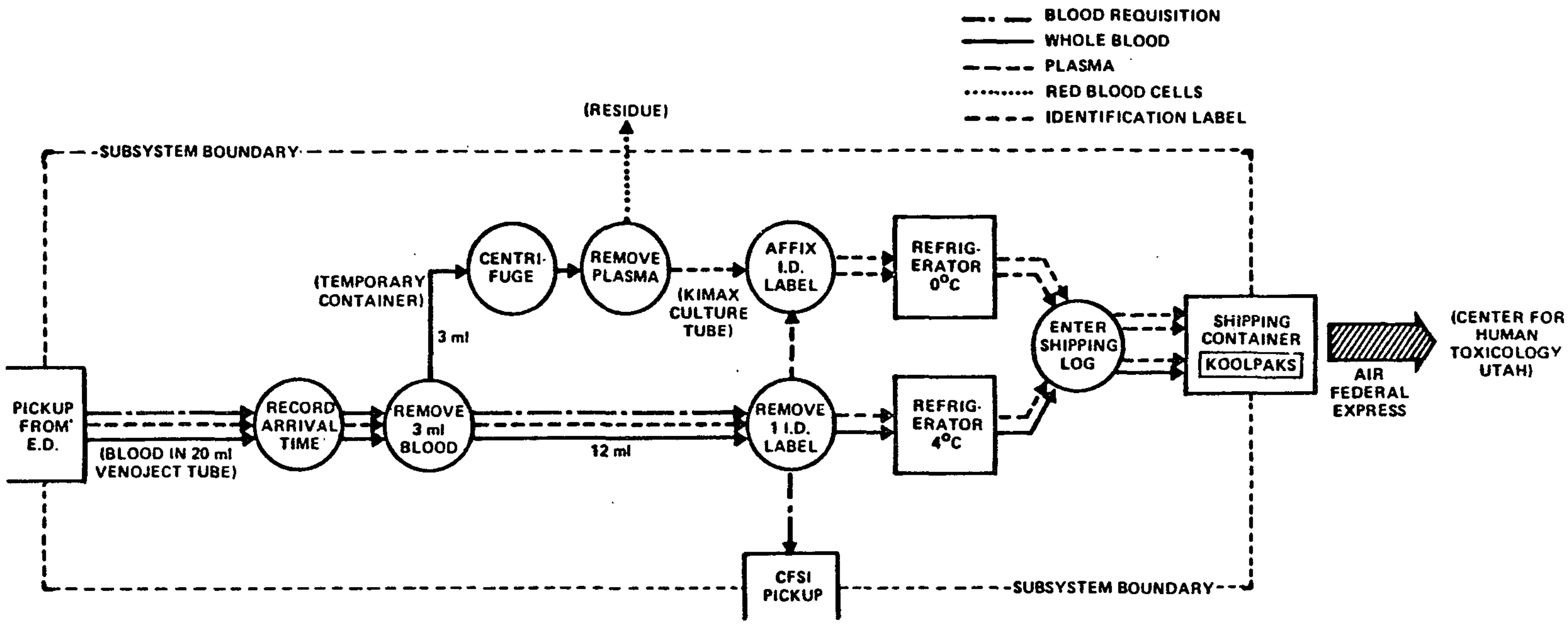


Figure 3 HOSPITAL CHEMISTRY LAB COMPONENT OF DATA COLLECTION SYSTEM

each properly labelled with the driver's identification number for the project. The plasma sample was then stored at 0^{o}C. while the whole blood was stored at 4^{o}C. Every two weeks the collected samples were placed for shipping into special insulating containers along with coolant materials to prevent spoilage. They were shipped to the Center for Human Toxicology (CHT) via air express, arriving within 24 hours of shipment. At CHT the samples were placed immediately into refrigerated storage to await disposition orders from CFSI.

While all but a very few of the blood and plasma samples were received intact at CHT, three samples were spoiled in the shipping process. Four others "disappeared" at an unknown point between packing and analysis.

University of Rochester Accident Investigation Unit (URAIU)

The project operations within URAIU accomplished three main functions:

(a) Case files were opened on every eligible driver and the required project forms were accumulated until the file was ready for release to CFSI;

(b) All drivers on "hold" status from the Emergency Department were asked to provide consent for their blood to be analyzed;

(c) All Monroe County police departments were visited regularly to obtain accident reports on all eligible drivers (including any not detected by the RGH Emergency Department)

In addition to these responsibilities, URAIU maintained regular contact with the RGH Emergency Department and Chemistry Laboratory to assist in the monitoring of those system components. For a period at the beginning of the project's Pilot Phase, URAIU conducted examinations of the crash vehicles owned by "in" drivers. This task was dropped when it became apparent that many vehicles were being examined too late or not at all* and the pursuit of vehicle examinations was detracting from the completion of other tasks.

Details of URAIU operations are shown in Figure 4.

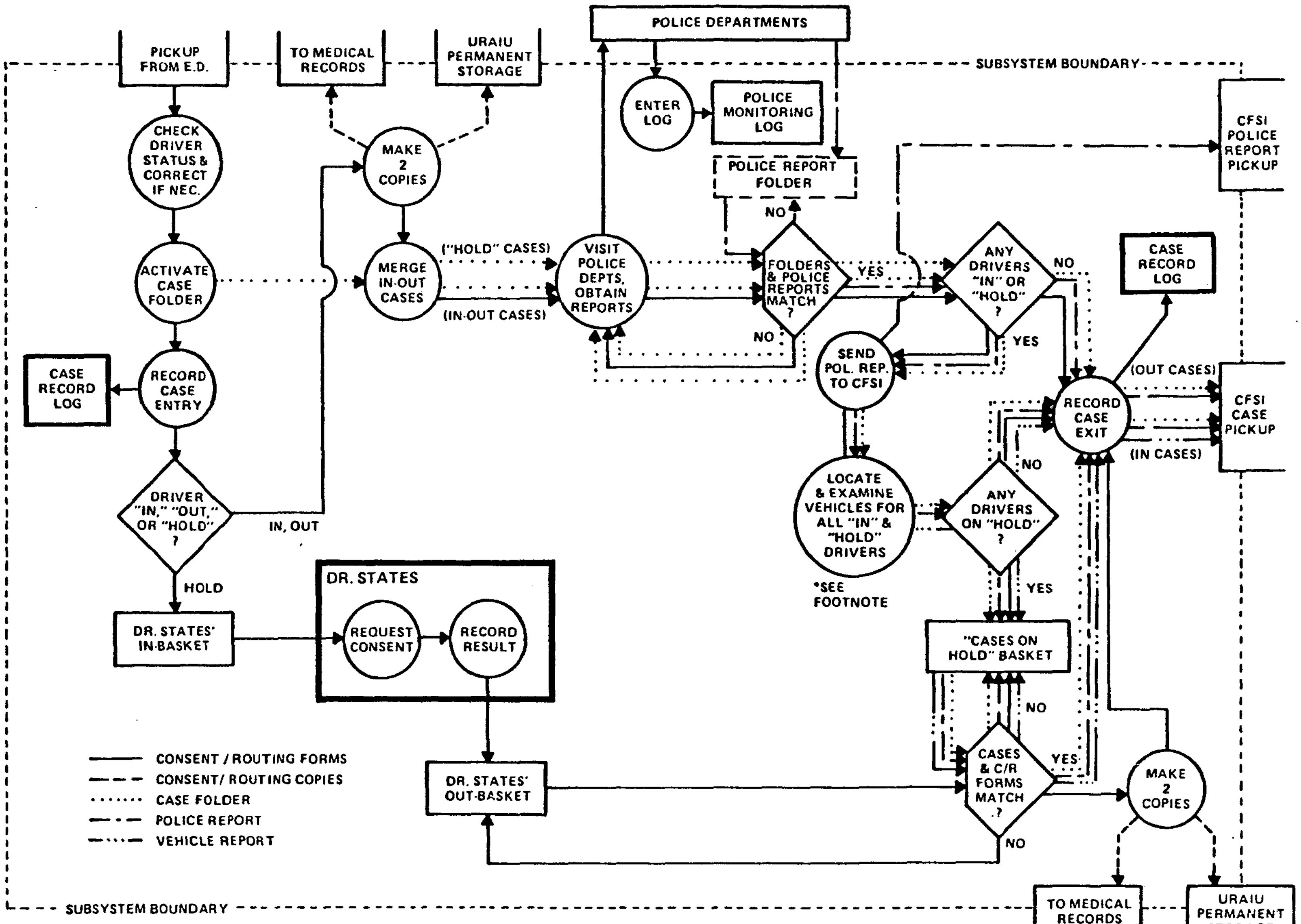
In the course of assembling the required forms, copies of a section of the Consent/Routing Form were made for retention by the hospital. This section included only the lines for consenting signatures, and it did not include the driver's project identification number. Thus, the hospital retained a record of consent without a linkage to the driver's blood analysis.

Visits to police departments were made every week to obtain a copy of the accident report (New York State form MV-104a) on every eligible driver, irrespective of whether the driver's status was "in," "out" or "hold". Periodically the accident report files of every police department within Monroe County were reviewed to identify all accidents in which the reporting officer indicated that an injured driver was taken to Rochester General Hospital. For those drivers which had not been detected by the Emergency Department, a further search of the hospital medical records was made to see if the driver had in fact appeared at the hospital.

Data Collection at CFSI

After designing the data collection system and briefing or training all the project personnel, CFSI continuously monitored the data collection system for quality control and prompt detection of problems. This was accomplished through regular contacts by the project administration and by a series of logs which traced the processing of drivers, blood samples, and data forms.

*Altogether, vehicle examination forms were submitted on 161 vehicles.



*VEHICLE EXAMINATIONS WERE ELIMINATED DURING PILOT PHASE.

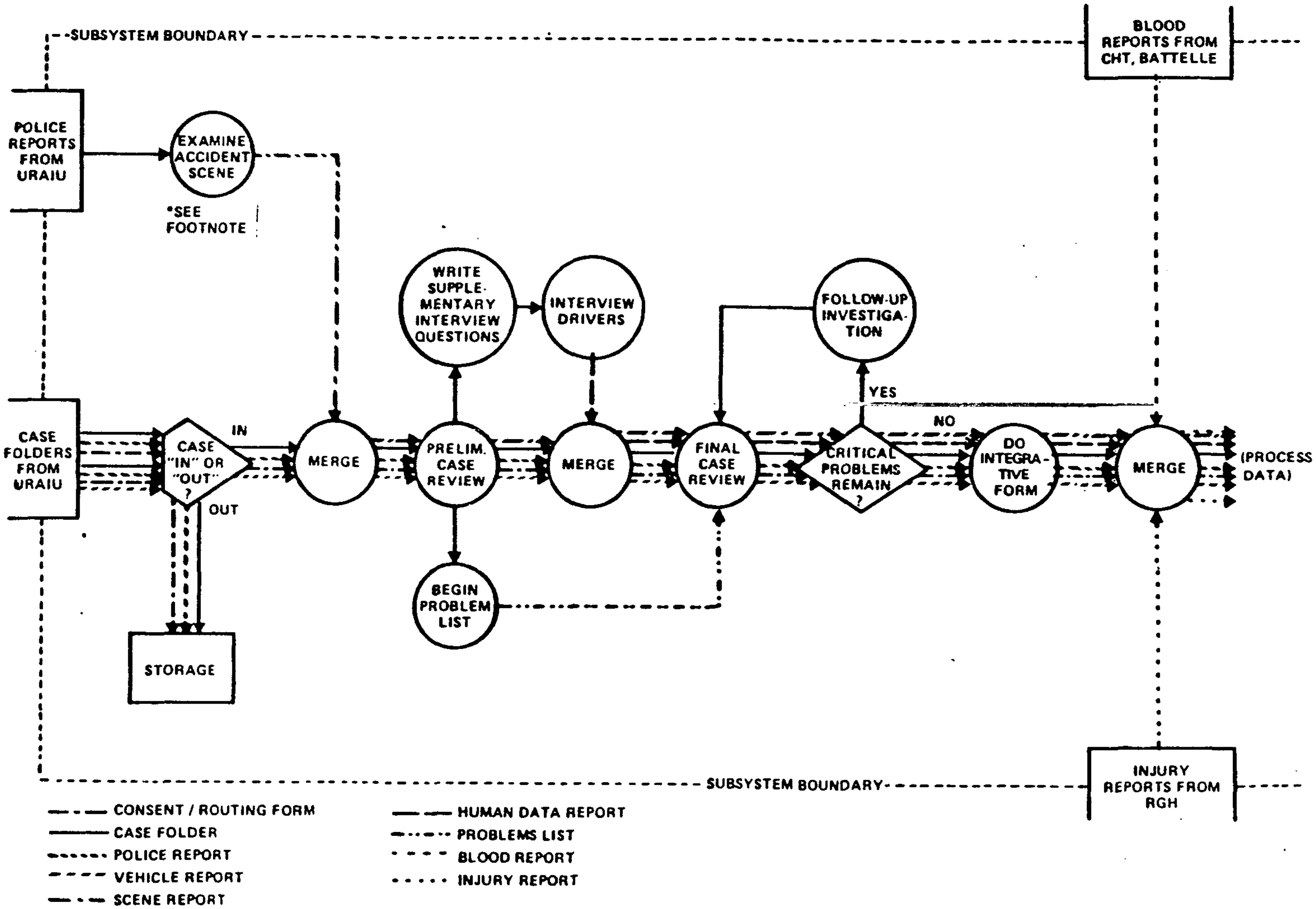
Figure 4 UNIVERSITY OF ROCHESTER ACCIDENT INVESTIGATION COMPONENT OF DATA COLLECTION SYSTEM

CFSI case investigators also were responsible for collecting some of the required data, as shown in Figure 5.

Scene examinations. During the project's pilot phase, the case investigators visited the scene of the "in" drivers' accidents, to record the permanent environmental features as well as accident evidence in the form of skid marks, residues and damage due to impacts. (See Appendix A for Environmental Data Form.) The scenes were visited, on the average, four days after the accident. (The investigators had to wait until a copy of the police report was obtained.) From these examinations and the police accident reports, the investigators drew scene diagrams depicting the crash vehicle paths and impacts in relation to the environment. These scene data were valuable in reconstructing the immediate events within the crash sequence, which often proved helpful to indicate probable causes of the accident and driver culpability. The data were costly to collect, however, so NHTSA decided that scene examinations should not be continued after the project's Pilot Phase. Scene examinations had been completed on 96 per cent (248) of the accidents of "in" drivers in the study at that time.

Driver interviews. Whereas scene investigations were collected only during the project's Pilot Phase, driver interviews were attempted on all drivers in the accidents of the "in" drivers, except in special cases. These were the accidents involving two or more drivers in which one had consented to a blood sample and one had refused. The refuser was regarded as having declined any study participation and therefore no attempt was made to interview him.

The driver interviews were considered essential to determining the details of what led up to each crash. Police reports were found frequently to have a paucity of the kind of detail desired for this study. Especially needed was information on what the driver was or was not doing just prior to the accident. In multivehicle accidents, drivers were asked about the actions of other vehicles as well as their own.



*SCENE EXAMINATIONS WERE ELIMINATED AFTER PILOT PHASE.

Figure 5 CALSPAN FIELD SERVICES COMPONENT OF DATA COLLECTION SYSTEM

During the Pilot Phase an extensive interview process was used in an effort to probe into all relevant details. The case investigators reviewed the police reports and the scene data beforehand, jotting down important points for inquiry as they did so. This effort included a preliminary "causal coding," to determine which items of information were missing to describe the crash events and their causal antecedents. The needed information was then specially addressed in the interview. After the interview, the relevant points were assembled in completing the Human Data Form. It became apparent during the Pilot Phase that this meticulous process was too time-consuming, requiring an average of nearly five hours of case investigator time per interview. Consequently, reductions in the preparation time and eliminations of less crucial data elements were made during the Pilot Phase. The Human Data Form subsequently used is shown in Appendix A-4.

The interviews were suspended at the end of the Pilot Phase (about nine months after data collection began), while NHTSA reassessed its funding situation in relation to revised cost estimates and project plans submitted by CFSI. Some of the drivers whose accidents occurred during the Pilot Phase had not yet been interviewed, and these were held in abeyance while awaiting the NHTSA decision on funds and data collection. Since driver blood sampling was continuing at Rochester General Hospital, these new drivers also went without interviews during the data collection suspension. Eventually, the decision was made to continue the interviews, which resumed about nine months after the suspension went into effect. This meant that the drivers had to recall crash events of nearly a year earlier, and it is likely that some drivers were lost through moving or other changes.

To locate the "in" drivers, their phone numbers and those of their next of kin were obtained from the hospital records. For the other drivers in the accidents of the "in" drivers, telephone numbers were looked up by referring to the names and addresses in the police accident reports. There were many drivers for whom no phone listing could be found, despite efforts to locate them. During the Pilot Phase, these drivers were sent letters explaining the project and requesting that they telephone CFSI "collect." Despite the use of follow-up letters, this practice elicited very few replies and was not continued beyond the Pilot Phase.

The outcomes of the efforts to interview drivers are shown in Table 2. As can be seen, the largest problem was with drivers for whom no number was available, despite the use of the hospital records, directory assistance, and so forth. The second largest problem was with drivers who were unavailable, despite up to 10 callbacks.

TABLE 2

Outcomes of Attempts to Interview Drivers

		N	%
(a)	Drivers interviewed	538	65.1
(b)	Refused	48	5.8
(c)	No phone listing (disconnected, unpublished number)	143	17.3
(d)	With phone, unable to reach (e.g., no answer)	80	9.7
(e)	Miscellaneous unavailable (e.g., died, jailed, stolen vehicle, hit-and-run driver)	17	2.0
	Total attempted to reach	826	100.0%
	Drivers in the accident cases but not attempted to reach because they had previously refused a blood sample.	27	

To minimize the problem of not-at-home drivers, repeat calls were distributed over different periods -- daytime, evenings, and weekends.

The accident investigators considered the number of unpublished numbers in this study more than that usually encountered in other projects. It is likely also that many of the phone disconnections resulted from people moving out of the area during the time since their accidents.

To encourage driver candor in describing their accidents, all the respondents were reminded at the beginning of the interview that the information was completely confidential, that it would be used only for research purposes, and that it is protected from disclosure by New York State law.

Data Elements

The data collected for this study were from five main sources:

(1) Police Accident Report (New York MV-104a): one per accident

(2) Human Data Form: One for each driver interviewed, usually one or more per accident

(3) Hospital Face Sheet (obtained from Rochester General Hospital): One for each eligible driver

(4) Consent/Routing Form: One for each eligible driver

(5) Blood sample: One for each "in" driver

Each one of these sources contains various kinds of information, much of which was extracted for the variables of this study. The sources are shown in Appendices A and B, while the specific variables extracted from them are shown on the code sheets in Appendix H. For general reference, Table 3 lists the kinds of information available from each of the sources.

Further Details of the Emergency Department Operations

To facilitate staff cooperation and understanding of the project, briefings were held at the Emergency Department before the study began and periodically during the course of the study. Written protocols describing their tasks step by step were provided to each secretary and nurse. The

TABLE 3. - BASIC DATA ELEMENTS AND SOURCES IN THE PROJECT

A. Source: Police Report (New York MV104a)

1. Presence of traffic control device/identification of device
2. Land usage of accident locale (residential, etc.)
3. Road character (straight vs. curves, level vs. grade vs. hillcrest)
4. Road surface condition
5. Type of accident (collision with . . . or non-collision)
6. Safety restraints used
   (Occupant injury data)
7. Number of vehicles in accident
8. Weather
9. Accident verbal description; sometimes scene sketches, sometimes road type
10. Age of driver
11. Sex of driver
12. Accident Date
13. Accident time
14. Accident day of week
15. Type of vehicle
16. Type of transport to hospital
17. Apparent contributing factors (including alcohol/drug impairment)
18. Pre-accident vehicle action
19. Location of first event
20. Citations, including DWI

(Continued)

TABLE 3. - (Continued)

B. Source: Human Data Form

1. Accident date
2. Type of vehicle
3. Accident verbal description: How accident happened and why
4. Weather
5. Visibility restrictions
6. Road surface condition
7. Relevance of road surface condition to accident
8. Travel direction
9. Travel lane
10. Right of way restrictions
11. View obstruction
12. Estimated travel speed
13. Driver age
14. Driver sex
15. Driver height
16. Number of occupants in vehicle
17. Driving experience
18. Type of medicine/drug taken within 6 hours of accident
19. Time of ingestion, prior to accident, of medicine/alcohol/drug
20. Driver emotional state just before accident
21. Driver physical state just before accident

C. Source: Hospital Face Sheet

1. Driver age
2. Driver sex
3. Marital status
4. (Injury description)
5. Type of transport to hospital
6. Treated and released vs. admitted to hospital

(Continued)

TABLE 3. - (Continued)

D. Source: Consent/Routing Form

1. Accident date
2. Driver age
3. Type of transport to hospital
4. Elapsed time between arrival at ED and drawing of blood
5. Result of request (s) for blood
6. ED observations of apparent alcohol/drug influence

E. Source: Blood Sample

1. Presence/absence of drugs/alcohol.
2. Quantification of drugs/alcohol.

Emergency Department physicians were also provided documents describing the study and soliciting their cooperation. Considerable effort was made to convey to the staff the importance and uniqueness of the research.

One problem that arose and was never entirely surmounted lay in the logistic difficulties of communicating to all staff members of the Emergency Department. At any one time the staff comprised around fifty fulltime nurses, 15-20 part-time nurses, about twenty secretaries, and 50-60 physicians. (Most of the physicians were part-time, working in the Department only a few hours each week.) Given the distribution of the staff over three shifts, rotating schedules for some staff members, and normal staff turnover, it was not possible to meet with all staff members simultaneously. All received the written communications, and briefings were repeated in order to be accessible to staff on different shifts. Individual contacts by a member of the research team were used to reach some staff members. Despite these efforts, misunderstandings of procedures did occur; because of the size and complexity of the E.D. staff, it was sometimes difficult to identify the source of any procedural problem and correct it.

To monitor the project activities in the Emergency Department, it was visited daily on weekdays by a member of the University of Rochester component. He also made regular visits to the Department on weekends and during the evening and night shifts. At these times, he would collect the completed Consent/Routing Forms for all eligible drivers and check on how the project was going. In addition, the department was visited about twice each week by a project monitor from CFSI. The purpose again was to maintain rapport with the staff, aid in any problems, and generally to facilitate project operations.

The Principal Investigator met with the staff at all briefings and on occasional visits.

Performance rates. To monitor the success the Emergency Department was having in obtaining blood samples from eligible drivers, a set of performance indices was created and updated monthly. These were:

(1) Detection rate -- Of all eligible drivers appearing at the Emergency Department,* the proportion identified by the staff.

(2) Request rate -- The proportion of all detected drivers who were asked to provide a blood sample for the study.

(3) Consent rate -- The proportion of those asked who consented.

(4) Useability rate -- The proportion of consenting drivers for whom a blood sample was drawn on time and which was shipped to the analysis laboratory without spoiling or damage.

(5) Inclusion rate -- The product of rates (1) through (4); the proportion of good, on-time blood samples obtained from all eligible drivers.

Computation of these rates proved extremely important, for they immediately revealed that some drivers were being lost to the study because of attrition throughout the system. During the first month's operation, eight per cent of the eligible drivers were lost through failure to detect them, failure to request lost another 14 per cent, refusals constituted an additional 16 per cent, and nonuseable blood samples comprised five per cent. Yet even these figures were excellent in light of the rapid declines that occurred thereafter:

*As determined by the search of police and hospital records.

	Month 1	Month 2	Month 3	Month 4
(1) Detection rate	92%	82%	65%	41%
(2) Request rate	85%	75%	71%	68%
(3) Consent rate	79%	50%	70%	60%
(4) Useability rate	91%	91%	95%	78%
(5) NET INCLUSION RATE	57%	28%	31%	13%

These declines were apparently due to a loss of the initial novelty and enthusiasm for the project amongst some Emergency Department members. Immediately upon discernment of a problem the project management began a troubleshooting effort. It appeared that staff performance was probably suffering from the lack of positive and timely reinforcement for their efforts. This recognition led to introduction of a "piecework" incentive program in which each secretary and nurse would receive a specified payment for each subtask performed in the processing of a driver; detection, requesting, receiving consent, and drawing a blood sample each earned a payment. The figures below show the dramatic results.

	Month 5	Month 6	Month 7	Month 8
(1) Detection rate	72%	97%	96%	97%
(2) Request rate	67%	91%	91%	89%
(3) Consent rate	64%	70%	62%	63%
(4) Useability rate	89%	96%	94%	95%
(5) NET INCLUSION RATE	28%	59%	51%	51%

The remedial measures had clearly succeeded. Those rates which directly reflected staff performance -- the detection, request, and useability rates -- all increased to beyond their levels of the first month. As may be expected, however, the driver consent rates were affected little by the staff's incentive program.

In succeeding months, measures to raise the performance rates further were explored, and two additional ones were introduced. The first resulted from a meeting with the Emergency Department supervisory staff. It was decided to give the supervisory nurses the responsibility of making sure all project tasks were performed properly. For every month the Inclusion Rate exceeded 55%, a financial bonus would be provided the entire staff, to be used for staff benefits. This measure succeeded in raising the performance rates slightly. From all indications the staff was making considerable effort to raise rates further, but some difficulties could not be surmounted. A certain attrition continually resulted from drivers who were unconscious or incoherent and no relative could be contacted. Other losses resulted from drivers who registered at the Emergency Department, but left before receiving medical attention. These cases lowered the request rate. Another problem resulted during periods of excessive hospital caseloads which delayed the transferral of patients from the Emergency Department to inpatient units. At these times the staff was extremely busy, and the research project tended to suffer accordingly.*

The second measure to raise the net Inclusion Rate concentrated on drivers. A detailed review of the performance data revealed that some nurses were consistently and significantly more successful in obtaining driver consent than were others, suggesting that something about their approach to drivers was inducing more cooperation. Interviews of these nurses revealed some common features,** and briefings were held to convey to the other nurses the "secrets of success" in eliciting driver consent. Although staff interest

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*It was understood and accepted by the project management that patient care would have priority over the research tasks.

**In general, it was found that these highly successful nurses used a low-key approach, in which the importance of the project was stated without a "hard sell." Rapport with the patient was built by attending to his/her medical needs before requesting the special blood sample. The successful nurses were <u>not</u> uniformly extroverted. The Emergency Department Administrator noted that the nurses in this group were highly competent generally, and confident of their abilities.

was high, no net gains in driver consent rates were obtained. Apparently the "winning ways" of the successful nurses were not easily acquired.

Paying the drivers for their blood was considered and rejected when a brief telephone survey of refusing drivers indicated that none would be induced to consent by payments as high as $40-$50. The total costs of such a program and the burden of an additional accounting system were considered prohibitive.

By this time the sample was approaching 500 drivers. With the NHTSA decision to limit the sample to that number, no further efforts to increase performance rates were made.

Period of Emergency Department involvement. The collection of blood samples began in May 1979 and ended on September 30, 1980, when the last "in" driver entered the study. The monthly number of eligible drivers appearing at the Emergency Department varied during this period from a low of 49 to a high of 84.

4. SAMPLE DESCRIPTION

In Chapter 2 the sample design and the chosen sample size of 500 injured drivers were discussed. Chapter 3 reported that many eligible drivers were lost to the study for various reasons, requiring that considerably more than 500 eligible drivers be seen at the RGH Emergency Department in order that there be 500 "in" drivers in the sample. In this chapter the obtained "in" driver sample is described and compared with the "out" drivers on various dimensions.

The "In" Drivers

An attempt was made to terminate sampling at exactly 500 "in" drivers, but after drivers on "hold" obtained their final status and ineligible drivers inadvertently sampled were eliminated, the final sample size was 497. The following are some general descriptive characteristics of this sample.

- The 497 drivers were in 475 different accidents; there were 22 crashes in which there were two "in" drivers.

- There were 854 drivers in the accidents of the "in" drivers, for an average of 1.80 drivers per accident.

- There were 877 vehicles in the accidents of the "in" drivers. (There were more vehicles than drivers because of accidents involving impacts with a driverless parked vehicle.)

- The sample comprised predominantly males and drivers under 30 (Table 4).

- The large majority sustained only minor injuries (Maximum A.I.S. rating =1) (Table 5).

TABLE 4. - AGE AND SEX CHARACTERISTICS OF DRIVER SAMPLE

Sex		%	N
	Men	62.4	310
	Women	37.6	187
		100.0	497

Age		%	N
	Under 20	18.7	93
	20 - 29	40.2	200
	30 - 39	15.1	75
	40 - 49	9.5	47
	50 - 59	8.5	42
	60 - 69	4.2	21
	70 and older	3.8	19
		100.0	497

Age X Sex

	Age		
	16-24	25-50	Over 50
Men	125	138	47
Women	71	81	35
	196	219	82

TABLE 5. - ABBREVIATED INJURY SCALE (A.I.S.) RATINGS IN THE DRIVER SAMPLE*

A.I.S.	N	%
0**	19	3.9
1	413	85.3
2	32	6.6
3	16	3.3
4	3	0.6
5	1	0.2
6	0	0
Indeterminate/ missing data	13	---
	497	100.0

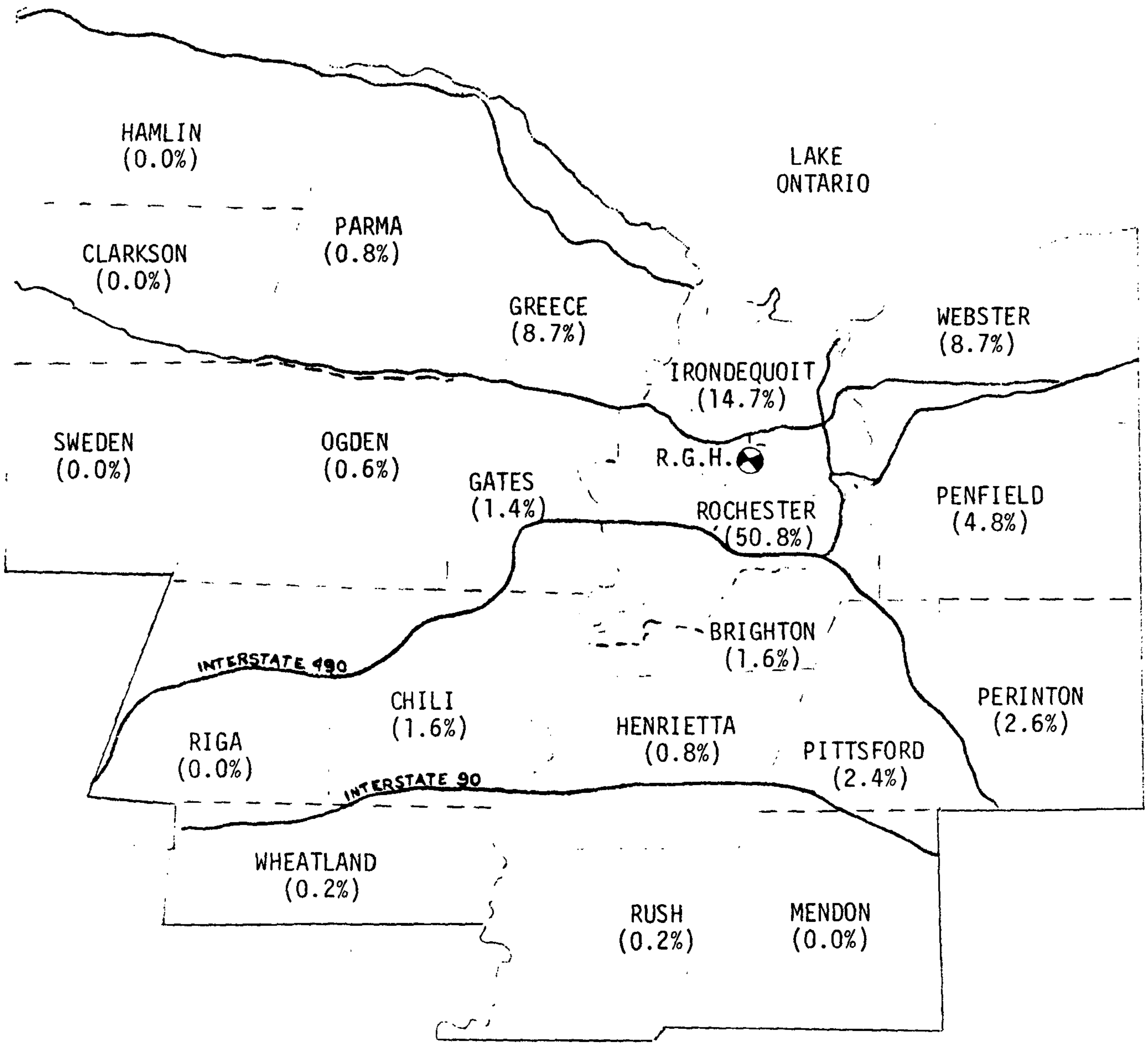
*The A.I.S. ratings were done by Dr. John D. States; tabulations are based on the maximum rating for each driver.

**A few sampled drivers were examined and found not injured.

Geographic distribution. Although Rochester General Hospital may serve a wide area of Monroe County, the accidents in the study mainly took place in geographically limited sections of the county. Figure 6 shows how the accidents were concentrated in the city of Rochester and the nearby suburbs in the northeast of the county. There was little representation of the suburbs south of Rochester, probably because there are at least two other major hospitals serving that area. Towns to the west of the city also provided very few of the accidents, probably due in part to lower traffic volume in these outlying areas, as well as to the availability of other hospitals there. Even within the city of Rochester the areas represented are limited, for most of the accidents were found to have come from the northern half of the city. This is no doubt due to the location of Rochester General Hospital near the city's northern boundary. Consequently, the accidents in the study should not be considered representative of accidents in Monroe County; they are likely to be more characteristic of accidents in northern Rochester and the towns closeby. As another consequence, only two per cent of the accidents in the study occurred in rural areas; 50 per cent were in urban areas and 48 per cent were in suburban areas.

"In" Drivers vs. "Out" Drivers

Chapter 3 described how eligible drivers could be lost to the study because they weren't detected, they weren't asked to participate, they refused, or their blood sample was spoiled or drawn too late. As a result, about half the eligible drivers were in the "out" group. Figure 7 shows the proportion of drivers lost from the different sources of attrition. It should be recognized that the figure summarizes the outcomes across the seventeen months of the study; later in the project the losses due to drivers undetected, unasked, or without good blood samples were significantly reduced. Nevertheless, it is important to compare the "ins" with the "outs" to see whether the former are likely to be a very atypical sample of the injured drivers appearing at Rochester General Hospital (and by extension, of injured drivers in general).



R.G.H. = ROCHESTER GENERAL HOSPITAL

- - - CITY, TOWN BOUNDARIES

—— MAJOR ROADS

FIGURE 6. THE STUDY SITE - MONROE COUNTY, NY
(%'s indicate portion of the total accident sample)

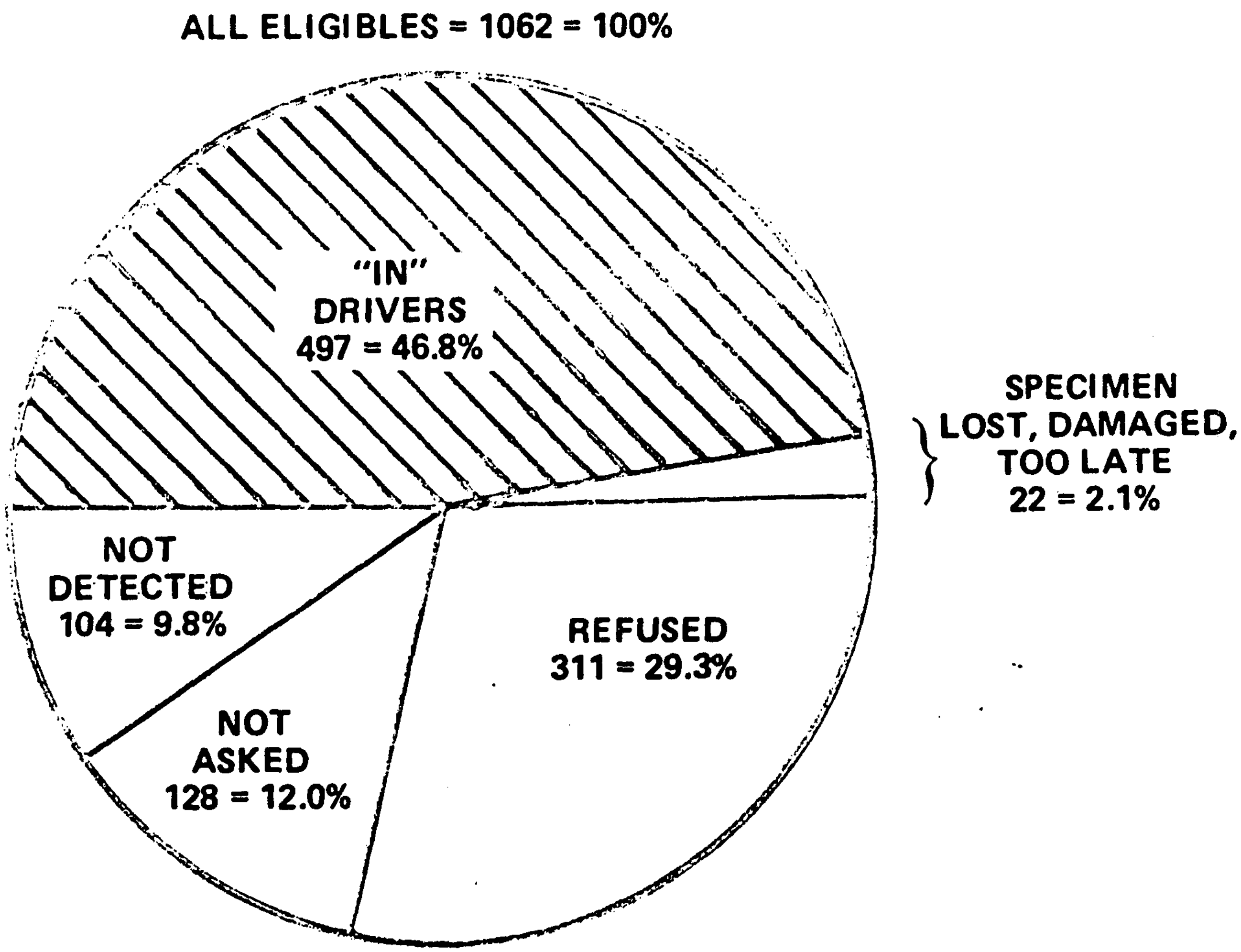


Figure 7. SOURCES OF SUBJECT ATTRITION

Table 6 compares all "in" and "out" drivers on several potentially important variables.* On most of these, the differences between the "ins" and "outs" are small. Differences seem large with respect to road type, but there were so many unknowns on this variable that the validity of the proportions is questionable.** On the more significant dimension of police indication of alcohol involvement, however, there is a substantial difference. If we assume that the police indications are fairly correct,*** it is apparent that the "in" sample underrepresents the proportion of alcohol-involved drivers, an undesirable situation. This indication is reinforced by the smaller portion of "in" drivers with accidents between midnight and 6 A.M., a time when drinking drivers are overrepresented on the road and in accidents. The slightly greater proportion of males, young drivers and culpable**** drivers among the "out" group also is consistent with a lower representation of alcohol-involved in the study sample.

As will be shown later, the sample of "in" drivers includes many more alcohol-involved drivers than the police reports indicate, so clearly drinking drivers were not simply lost to the study.

It is of some interest to ask whether the loss of alcohol-involved drivers in the "out" group was due to the refusers or some other subgroup, to see if there are further clues as to the nature of drivers lost to the study. Table 7 compares the subgroups on the various key variables. The most important results in the table are that driver culpability and police indications of alcohol are greatest among the undetected and unasked drivers. The refusing drivers, who constituted the bulk of the "out" drivers, differed little from the "in" drivers on the two variables.

*Explanations of how the variables were coded are found in Chapter 5.
**Road type is unknown mostly among "out" drivers because no scene examinations or interviews were done for that group.
***Data in Chapter 7 will support this.
****The sources of culpability data are described in Chapter 5.

TABLE 6. - COMPARISON OF "IN VS "OUT" DRIVERS

(497 "in" drivers, 565 "out" drivers)

	IN	OUT
AGE		
≤ 20	18%	21%
21-30	40%	41%
31-64	35%	32%
≥ 65	7%	5%
Unknown	--	1%
SEX		
Male	62%	65%
Female	38%	34%
Unknown	--	1%
TIME OF DAY		
Midn - 6AM	17%	24%
6AM - Noon	21%	14%
Noon - 6PM	37%	33%
6PM - Midnight	24%	29%
Unknown	2%	1%
VEHICLE TYPE		
Automobile	78%	74%
Pkckup/Van/Utility	9%	5%
Medium/Heavy Truck	1%	2%
Motorcycle	10%	13%
Other	1%	--
Unknown	2%	6%
VEHICLE STATUS		
First striking vehicle	63%	59%
Second striking vehicle	34%	33%
Other involved vehicle	2%	1%
Unknown	1%	6%
ENVIRONMENT		
Urban	51%	50%
Suburban	47%	48%
Rural	2%	2%
Unknown	--	--

	IN	OUT
ROAD TYPE*		
Limited access/other divided	10%	21%
Other multilane - 2 way	38%	26%
2 lane - 2 way	41%	36%
One way	1%	1%
Driveway/Parking lot/Ramp	9%	15%
Other	--	2%

*Unknowns removed (58 "ins", 375 "outs")

	IN	OUT
POLICE INDICATION OF ALCOHOL		
Yes	10%	17%
No	85%	77%
No police report	5%	6%
ACCIDENT TYPE		
Single driver	27%	29%
Rear end	19%	16%
Same direction - sideswipe	2%	3%
Head on	6%	5%
Opposite direction - sideswipe	1%	1%
Turn across path	12%	12%
Turn into path	10%	6%
Intersecting paths	14%	14%
Backing	1%	1%
Other	4%	5%
Unknown	3%	8%
CULPABILITY		
Culpable	40%	45%
Contributory	4%	3%
Culpable/Contributory	11%	7%
Contributory/Neither	10%	6%
Neither	28%	29%
Unknown	6%	9%
INJURY LEVELS (A.I.S.)		
Level 0	4%	7%
Level 1	83%	72%
Level 2	6%	7%
Level 3	3%	6%
Level 4 or higher	1%	2%
Unknown	3%	7%

TABLE 7. - COMPARISON OF DRIVERS AMONG ALL STATUS GROUPS

	"Ins"	"Out Drivers"			
	Drivers (n=497)	Refused (n=311)	Undetected (n=104)	Unasked (n=128)	Lost* (n=22)
AGE					
≤ 20	18%	23%	22%	16%	23%
21-30	40%	38%	41%	45%	45%
31-64	35%	33%	32%	31%	23%
≥ 65	7%	5%	5%	5%	5%
Unknown	0%	1%	0%	2%	5%
SEX					
Male	62%	68%	68%	60%	50%
Female	38%	32%	32%	38%	50%
Unknown	0%	0%	0%	2%	0%
TIME OF DAY					
Midnight-6AM	17%	26%	29%	18%	5%
6AM-Noon	21%	14%	10%	18%	14%
Noon- 6PM	37%	33%	26%	34%	55%
6PM - Midnight	24%	27%	33%	30%	27%
Unknown	2%	0%	3%	0%	0%
VEHICLE TYPE					
Automobile	78%	72%	76%	78%	77%
Pickup/Van/Utility	9%	6%	5%	5%	5%
Medium/Heavy Truck	1%	1%	1%	2%	5%
Motorcycle	10%	13%	18%	9%	9%
Other	1%	0%	0%	1%	0%
Unknown	2%	8%	0%	5%	5%
ENVIRONMENT					
Urban	51%	52%	45%	48%	59%
Suburban	47%	48%	53%	48%	41%
Rural	2%	1%	2%	4%	0%
Unknown	0%	0%	0%	0%	0%
ROAD TYPE **					
Limited access/ Other divided	11%	21%	21%	24%	17%
Other multilane - 2-way	38%	30%	14%	24%	25%
2 lane - 2 way	41%	36%	28%	38%	50%
One way	1%	0%	0%	2%	0%
Driveway/Parking Lot/ Ramp	9%	14%	34%	7%	8%
Other	0%	0%	3%	5%	0%

*Consented, but became lost to the study because blood was drawn overtime or clotted.

**Includes large numbers of unknowns, omitted from the proportions.

(Continued)

TABLE 7. - (Continued)

	"In"	Refused	Undetected	Unasked	Lost*
POLICE INDICATION OF ALCOHOL					
Yes	10%	13%	25%	22%	0%
No	85%	80%	75%	70%	86%
No police report	5%	7%	0%	9%	14%
ACCIDENT TYPE					
Single driver	27%	26%	37%	32%	14%
Rear end	19%	16%	17%	16%	18%
Same direction - sideswipe	2%	3%	1%	2%	5%
Head on	6%	6%	3%	5%	0%
Opposite direction - sideswipe	1%	1%	1%	0%	9%
Turn across path	12%	11%	13%	12%	9%
Turn into path	10%	6%	8%	4%	9%
Intersecting paths	14%	14%	12%	14%	18%
Backing	1%	1%	2%	1%	0%
Other	4%	6%	6%	4%	9%
Unknown	3%	10%	1%	9%	9%
CULPABILITY					
Culpable	41%	41%	62%	48%	41%
Contributory	4%	2%	4%	2%	0%
Culpable/Contributory	10%	8%	6%	5%	9%
Contributory/Neither	10%	5%	5%	9%	9%
Neither	28%	33%	20%	26%	36%
Unknown	6%	11%	4%	11%	5%
INJURY LEVELS (A.I.S.)					
Level 0	4%	4%	15%	6%	0%
Level 1	83%	81%	60%	61%	73%
Level 2	6%	5%	8%	8%	18%
Level 3	3%	5%	6%	6%	9%
Level 4 or higher	1%	1%	0%	5%	0%
Unknown	3%	4%	12%	13%	0%

An obvious question is why alcohol involvement should be so high among the drivers not detected or not asked for a blood sample. Part of the answer to this is provided by the injury levels in Table 7. Among those not detected, there were relatively high proportions of drivers with unknown injuries or with no injuries. The former are most likely to be in the group of drivers who registered at the Emergency Department and then walked out without being seen by the medical staff, hence no injury record and no "detection" for the study. Those without injuries, on the other hand, may have been sent to the hospital by police because their impairment suggested possible injuries. Why they escaped detection is not clear. As to the drivers not asked for blood, their injury levels were the highest of all groups. Since alcohol-involved drivers are likely to be in more severe accidents (see Introduction), the severely injured would be expected to include more drinking drivers. At the same time, severely injured drivers are less likely to be asked for blood if unconscious or incoherent.

Clearly, the loss of the undetected and unasked drivers was unfortunate for the study. Although the size of those groups was reduced to about three per cent and six per cent of eligible drivers in the later months of the study, the problems of "left without being seen" and unconscious/incoherent drivers with no relatives present were difficult to overcome.

The ETOHOUT Group

While the "in" drivers constituted the basic subject group in this study, other drivers of interest are the "out" drivers for whom there were behavioral indications of intoxication. These are labelled the ETOHOUT group. They include any drivers judged to be alcohol-involved by the police or by RGH nurses. The police accident reports included a Driving While Intoxicated citation or a notation that alcohol contributed to the crash. The nurses at the RGH Emergency Department noted on each driver's Consent/Routing Form whether he exhibited any evidence of alcohol, such as an alcoholic breath, staggering, and so forth. The nurses used their own judgment as to whether any abnormal behavior was a symptom of drunkenness.

Altogether, 128 (22.6%) of the "out" drivers were thus identified as alcohol-involved. Of these, 38 per cent were identified only by the police 25 per cent only by the nurses, and 37 per cent by both.* Although these judgments probably underestimate the total number of alcohol-involved drivers in the "out" group, the ETOHOUTS provide a useful comparison group for double-checking some of the results for the alcohol-involved "in" drivers.

*Project records show that alcohol notations by the nurses increased during the course of the project, particularly after a special section for recording this information was added to the Consent/Routing Form. Had this been emphasized more during the early part of the project, the nurses probably would have noted more drivers exhibiting impaired behavior.

5. DATA PREPARATION

Before the analyses could be performed to answer the basic questions of the study, the variables necessary to answer those questions had to be extracted out of the mass of raw material in the various investigative forms, as well as in the blood samples. An important part of this process was data generation, for measurements and derivations were applied to the blood samples and crash descriptions, producing new variables. The data generation is based on detection rules or algorithms. Main examples of generated data are the substances detected in a driver's blood, and collision types which are classifications of the crashes according to vehicle paths and impact details. The processes for generating these and other variables are described in this chapter.

Drug Identification

At the Center for Human Toxicology of the University of Utah*, the blood and plasma samples were tested for the substances listed in Table 1. (The plasma was needed only for the detection of Δ^9-tetrahydrocannabinol [Δ^9-THC], the pharmacologically active constituent of marijuana.) In general, the testing procedure could be divided into two major areas; the initial stage involved a series of analytical tests that provided a presumptive identification of a drug. The second stage consisted of further analytical procedures to confirm and quantitate any drugs and/or metabolites presumptively identified in the first stage.

A technical description of the specific analytic procedures is found in Appendix F.

*The Center for Human Toxicology was designated as the subcontractor by the National Highway Traffic Safety Administration, in coordination with the National Institute on Drug Abuse.

Parent drugs and metabolites. If a driver had ingested one of the substances tested for, the blood/plasma analyses may detect and quantify (a) the substance itself and/or (b) a metabolite, which is a product resulting from the body's metabolizing the substance. Some substances are detected only through their metabolites; the metabolite signifies the presence of the "parent" drug. For example, flurazepam (Dalmane®), a benzodiazepine, is rapidly metabolized to N-desalkylflurazepam and this compound is usually the only one detected in plasma samples collected after the ingestion of this drug. However, in the majority of cases, the parent drug is detected when blood or plasma is analyzed. Occasionally, a difficulty in interpreting the analytical results can arise when a number of drugs form a common metabolite. For example, desmethyldiazepam is a metabolite of chlordiazepoxide, (Librium®), diazepam (Valium®), clorazepate (Tranxene®) and prazepam (Centrax®), and may therefore be detected following the ingestion of any of these drugs. If desmethyldiazepam alone is detected, however, it is likely that either clorazepate or prazepam were ingested. For the other benzodiazepines, this metabolite would be detected together with parent drug (diazepam) or with other metabolites (in the case of chlordiazepoxide).

In the blood analysis reports received from the Center for Human Toxicology at the University of Utah, all parent substances and metabolites found in each driver's blood/plasma specimens were reported, along with the concentrations of each. Those drugs known to have been administered within the RGH Emergency Department were noted. (This information was initially recorded on the Consent/Routing Forms and forwarded to Utah.) Drugs thus administered were not counted in the compilation of drug incidence rates.

A complete report of the analyses outcomes submitted by the Center for Human Toxicology is given in Appendix B*. These reports were not used directly in subsequent data analyses by CFSI, however, for they first needed to be coded, as described next.

*The form of the reports was determined by the Center for Human Toxicology and the responsibility for the reports is theirs.

Processing the blood/plasma reports. Although quantities were specified for all detected substances, the concentrations were used only for ethanol (in the form of Blood Alcohol Concentrations, or BAC's) and for Δ^9-THC (the cannabis active agent). These substances were found in sufficient numbers of drivers to make possible limited analyses relating concentration to dependent variables such as driver culpability. While diazepam and other minor tranquilizers were detected in a significant number of drivers, the blood concentrations were not related to the dependent variables because of the extreme difficulty in determining the pharmacological contribution of the metabolite.

Subsequent data analyses were made in terms of parent drugs. For those cases where a metabolite could have resulted from more than one parent drug the basic assumptions used were as follows:

a) If a metabolite is found in combination with one or more of its possible parent drugs, only the parent drug is coded as present. For example, if diazepam and desmethyldiazepam were both detected, only diazepam was coded as present.

b) If a metabolite alone is detected, then a variable representing the drug grouping is coded. For example, if desmethyldiazepam alone was detected, then a variable representing clorazepate and prazepam was coded.

Although a particular metabolite could have resulted from the ingestion of more than one parent substance, it was felt that the above conservative rules were necessary to avoid exaggerated counts of the number of drugs detected or the incidence of multiple usage of drugs.

Programming rules were written only for the substances actually found in the blood/plasma samples. (Many of the substances listed in Table 1 were not detected in any drivers.) The programming rules are presented in Appendix G.

Assessing Culpability

A modified version of Perchonok's (1978) rating scale of driver culpability was used by the trained coders in this study. The scale values in abbreviated form, are listed below.*

(1) Culpable - The subject vehicle was the first to create the dangerous situation.

(2) Culpable/contributory - Driver had some responsibility, but it is not clear whether he was culpable or contributory.

(3) Contributory - Another vehicle or agent created the dangerous situation,but the subject driver could have avoided the crash by a normal avoidance maneuver.

(4) Contributory/neither - At most, driver's responsibility was only contributory.

(5) Neither culpable nor contributory - Driver had no responsibility for the accident.

Two coders were trained to use this scale. During training, they did practice coding of accident cases in Perchonok's (1978) study and compared their ratings with those assigned in the earlier study. Coding reliability on the cases of this study was checked at four points, at intervals from the

*Detailed definitions are given in the Coding Manual in Appendix C.

beginning to the end of the coding. At these times, each coder recoded cases of the other coder, and agreement between them was determined. In the four successive sets of 25 cases each, the correlations between the coders (by Pearson r) were: 0.92, 0.82, 0.92, and 0.93. Thus, a high degree of inter-coder agreement was indicated.

As a further check, the same four sets of cases were submitted to Perchonok to code, and his correlations with the coders averaged as follows: 0.67, 0.63, 0.83, 0.92. There is an apparent practice effect here, probably due to the fact that it had been some years since Mr. Perchonok had done this kind of coding. By the fourth data set, he seems to have reached the same high level of agreement with the coders that they had with each other.

Determining Collision Type

Another important dependent variable as stated in Chapter 2 is the type of collision in which the driver is involved. Most collision taxonomies describe crashes holistically, whereas the taxonomy needed here was one that designates the role of a specific vehicle in the crash. For example, instead of simply designating a collision as a head-on type, it is more important to determine whether a driver's vehicle was one which crossed the road centerline into the path of another vehicle, or if his vehicle was the "victim" of another vehicle which crossed the centerline.

To provide a comprehensive way to analyze for collision types, coders were trained to use the CALAX system, a taxonomy of collision types that had been developed by CFSI. The system is easily learned by coders, and it meets the requirement of identifying specific vehicles in collisions. The coder simply assigns the most appropriate vehicle code from a series of diagrams depicting collision types (Figure 8). From these codes, collisions can be classified at three different levels.

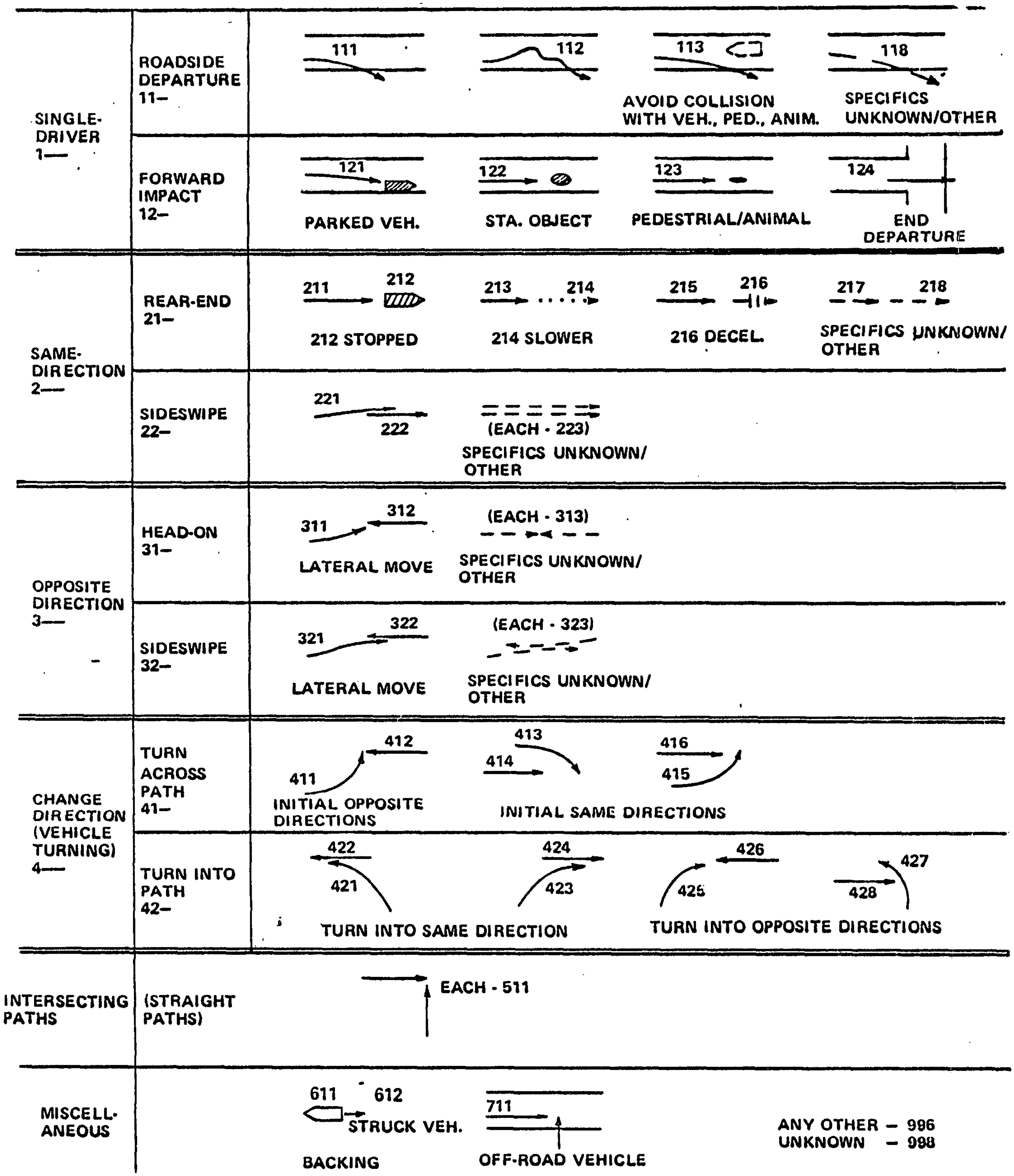


Figure 8. CALAX COLLISION CODING SYSTEM

Detailed level (CALAX 1) - 43 types identified by the three-digit numbers in Figure 8.

Intermediate level (CALAX 2) - 11 types comprising the groups assigned two-digit numbers in Figure 8. (Role of specific vehicles not distinguished)

Gross level (CALAX 3) - 6 types comprising the groups assigned single digit numbers in Figure 8. (Role of specific vehicles not distinguished)

The CALAX coding reliability for the same cases used in the culpability checks was determined, with results as shown in Table 8. It can be seen that the coders achieved high agreements with the CALAX system, especially after the first data set. The system was also found to account for 92 per cent of the collisions, with only four per cent in the "other" category, and four per cent unknown. The CALAX system thus proved to be both comprehensive and highly reliable for the analysis of collision types.

Coding Other Data

After an analysis plan was developed for answering all the research questions listed in Chapter 1, the variables needed for the analyses were listed, along with their information sources in the various raw data forms, including the police reports. Many of the variables were field-coded on the forms, so the data preparation required only a tranferral from those forms onto the code sheets to be used in keypunching.

All the code sheets, which identify the values taken by all the raw variables used, are provided in Appendix H.

TABLE 8. - INTERCODER RELIABILITY OF COLLISION TYPES

CALAX System	Set 1	Set 2	Set 3	Set 4
Detailed level (43 types)	70%	81%	92%	96%
Intermediate level (11 types)	83%	92%	96%	96%
Gross level (6 types)	83%	96%	96%	96%

6. COMPARATIVE RESULTS AMONG SUBSTANCE GROUPS

Having reviewed the research methods used in this study, we can now return to the questions posed in the Introduction. This chapter addresses those questions which compare the various alcohol-drug groups, while Chapters 7 and 8 will look more closely at the crashes of specific substance-involved drivers.

What Were the Incidence Rates of the Various Substances?

The results of the blood toxicological analyses are shown in Table 9. From Part A of the Table it can be seen that 38 per cent of the specimens contained at least one of the substances tested for, while approximately 11 per cent contained two or more substances. The parent drugs identified are included in Part B; it is worthwhile noting that only eighteen individual drugs were identified.

Alcohol was definitely the predominant substance found. At 25 per cent, its incidence closely corresponds to that found in other studies of injured drivers. (See Introduction.) Δ^9-THC, the marijuana agent, was the second most common substance*, while diazepam was the third. All remaining substances were found in very low incidences, some appearing in only one specimen each.

It is useful to show the incidences within pharmacological groups, as is done in Part C of Table 9. "Drugs of abuse" and tranquilizers were the largest. No antihistamines were detected, which is surprising. (It was found in two per cent of the fatally injured drivers, in the 1980 Ontario study by Cimubra et al.) The incidence of cocaine, while low at ten drivers, may reflect the recently reported increase in use of this drug (Carr, 1979;

*In the remainder of the report, Δ^9-THC is abbreviated to THC.

TABLE 9. - SUMMARY OF BLOOD SAMPLE ANALYSES

A. Overview

	N	%*
Total samples analyzed (= # "in" drivers)	497**	100.0
Samples with substances detected (excludes ED-administered Medications)	188	38.1
Samples with 2 or more substances	52	10.5

B. Specific Substances Detected***

Specific Substances Detected***	Pharmacological Class	N	%*
Ethanol	Central Nerv. Sys. Depressant	125	25.3
Δ^9-THC	?	47	9.5
Diazepam	Tranquilizer	31	6.3
Cocaine	Central Nerv. Sys. Stimulant	10	2.0
Phenobarbital/Primidone	Anticonvulsant	8	1.6
Chlordiazepoxide	Tranquilizer	5	1.0
Lidocaine	Anesthetic	4	0.8
Methaqualone	Sedative-Hypnotic	4	0.8
Butalbital	Sedative-Hypnotic	3	0.6
Flurazepam	Sedative-Hypnotic	3	0.6
Secobarbital	Barbituate Sed-hypnotic	2	0.4
Amobarbital	Barbituate Sed-hypnotic	1	0.2
Carbamazepine	Anticonvulsant	1	0.2
Chloral hydrate	Sedative-Hypnotic	1	0.2
Codeine	Narcotic Analgesic	1	0.2
Meprobamate	Nonbarb. Sedative-Hypnotic	1	0.2
Phenytoin	Anticonvulsant	1	0.2
Propoxyphene	Narcotic Analgesic	1	0.2
Chlorazepate/Prazepam	Tranquilizer	1	0.2

C. Drug Group Detected

Drug Group Detected	N	%*
"Drugs of abuse" (THC, cocaine)	54	10.9
Tranquilizer	37	7.5
Sedative-Hypnotic	14	2.8
Anticonvulsant	10	2.0
Analgesic	2	0.4

*Percentages are based on 494 whole blood samples and 494 plasma samples and are not additive, for a sample can contain more than one substance.

**Three of the samples involved only THC analysis; three other samples involved only whole blood analysis.

***Caffeine, while on the test list (Table 1), does not appear here because the Center for Human Toxicology determined it was not present at impairment levels.

Demarest, 1981), or it may reflect the sensitive analytical procedures used to detect cocaine and its metabolite (benzoylecgonine) in this study.

Of the various substances, the only ones that provide sufficient numbers for statistical analyses are ethanol, THC, and the tranquilizer group. Subsequently, attention will be focused primarily on these groups.

Ethanol and THC concentrations. The levels of ethanol and Δ^9-tetra hydrocannabinol that were found are shown in Table 10. It can be seen that most of the alcohol-involved drivers had intoxication-level BAC's (.10% or greater), and many of these were at very high BAC levels exceeding .20%. Since such high levels are likely to be reached only by those accustomed to drinking frequently and in substantial amounts, the involvement of problem drinkers in the alcohol-involved group is suggested.

The THC concentrations varied widely, from barely detectable traces to .011 mcg/ml. Table 10 shows that THC was found mostly at concentrations of .002 mcg/ml or less.

It should be noted that the alcohol and THC concentrations found will not exactly represent the concentrations at the time of the accidents, for up to four hours may have elapsed by the time the blood was drawn.* Since BAC's tend to peak in one to 1-1/2 hours after ingestion, while THC levels peak within a few minutes,** and since ingestion of these substances presumably occurred at some time prior to the accidents, it may be expected that the alcohol and THC levels would generally be lower among drivers whose blood was

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*In seven instances, blood was drawn between four and five hours since the accident, contrary to specifications. Because blood samples were hard to get, it was decided to include these few late samples rather than further reduce the useable driver sample.

**Peaks will vary by method of ingestion and among individuals. Ohlsson et al., (1980) found THC levels peaking within three minutes (the first time period sampled), while Owens et al., (1981) found peaks at ten minutes (again, the first time period sampled), when ingestion was via smoking.

TABLE 10. - BLOOD CONCENTRATIONS OF ALCOHOL AND TETRAHYDROCANNABINOL

Blood Alcohol Concentration	N	%
Negative	369	74.7
.01 - .04%	4	0.8
.05 - .09%	24	4.9
.10 - .14%	37	7.5
.15 - .19%	26	5.3
$\geq$ .20%	34	6.9
	494	100.0

Δ^9-THC Concentration	N	%
Negative	447	90.5
> 0 to .002 mcg/ml	27	5.4
.003 - .004	10	2.0
.005 - .006	4	0.8
.007 - .008	3	0.6
$\geq$ .009	3	0.6
	494	100.0

drawn later rather than soon after their accident. Table 11 shows that this was somewhat true for ethanol, although the effect is not distinct. The lack of a strong relationship between sampling time and BAC is probably due in part to the fact that time of ingestion was unknown.

Judging by the peak THC blood levels that subjects have attained after smoking one marijuana cigarette (Ohlsson et al., 1980; Owens et al., 1981) the THC levels found in this study appear fairly low.* While low levels could be found simply because low dosages were taken, it seems likely that they resulted from the passage of sufficient time for metabolism to significantly reduce the blood levels of THC. The fact that there were no differences in the THC distributions of the earlier and later blood samples (Table 11) suggests that, at the time of the blood sampling, the THC levels of most of the drivers were decreasing at a low rate. THC absorption curves (Ohlsson et al., 1980; Owens et al., 1981) for smoked marijuana indicated that beyond one hour since ingestion, THC levels are generally low and decreasing slowly.

Multiple drug use. Concern is sometimes expressed about multiple drug use by drivers, where two or more drugs simultaneously present may have additive or interactive ("synergistic") impairment effects. As Table 9 showed, nearly 11 per cent of the drivers had multiple substances in their blood. The most frequent combination by far was alcohol plus something else; of the 52 drivers with substance combinations, 45 had alcohol in their systems.

The main combinations are shown in Table 12. Note that while tranquilizers were usually found without alcohol, cannabis and cocaine were commonly combined with alcohol. That eight out of ten cocaine users had also ingested alcohol is consistent with the statement by Carr (1979, p. 46) that "Cocaine users are clearly multiple drug users."

*Ohlsson and colleagues reported peaks ranging from .033 to .118 mcg/ml, while Owens and colleagues showed an average peak around .040 mcg/ml.

TABLE 11. - ALCOHOL AND THC CONCENTRATIONS IN RELATION TO TIME SINCE ACCIDENT

	Time from Accident to Drawing of Blood Sample*		
BAC - %	0 - 1.0 Hr.	1.1 - 2.0 Hr.	2.1 + Hr.
0	73.3%	71.6%	79.9%
.01 - .09	4.9	6.7	3.9
.10+	21.8	21.6	16.2
	100.0%	100.0%	100.0%
n	101	208	154

THC - mcg/ml	0 - 1.0 Hr.	1.1 - 2.0 Hr.	2.1 + Hr.
0	91.1%	90.3%	90.3%
> 0 to .002 mcg/ml	4.9	5.8	5.8
≥ .003 mcg/ml	4.0	3.9	3.9
	100.0%	100.0%	100.0%
n	101	207	155

*Time was unknown in 31 cases.

TABLE 12. - MAIN SUBSTANCE COMBINATIONS FOUND

Substance	N Drivers	By itself	Combined with Ethanol	Combined with other	Total
Ethanol	125	64.0%	---	36.0%	100.00%
THC	47	42.6	51.0	6.4	100.0
Tranquilizer	37	54.1	32.4	13.5	100.0
Cocaine	10	10.0	80.0	10.0	100.0

Driver characteristics. The main substance groups were found to exhibit distinctive patterns with respect to driver age and sex. Table 13 shows the tranquilizer group to comprise considerably more drivers in the 25 - 50 age range than did any other driver group; the sex distribution is similar to that of drugfree drivers. In contrast, the alcohol, THC, and cocaine groups included definitely more young drivers and hardly any over age 50, and they were predominantly male as well.

The variable SUBSAMPL. All the "in" drivers were divided into mutually exclusive substance groups for many of the subsequent analyses, and these groups comprised values of a derived variable, SUBSAMPL (Table 14). These nonoverlapping groups are independent and comparable statistically. Note that the drivers having only alcohol, only THC, or only tranquilizers in their blood samples are distinguished. With such groups it is possible to examine correlates of each of the main substances, without confusion caused by the presence of other substances. There were sufficient numbers to do this only with alcohol, THC, and tranquilizers, and even with the last two, the subsample sizes limited the analyses possible.

TABLE 13. - DRIVER CHACTERISTICS AND SUBSTANCES DETECTED

Substance Group*	n	Age 16-24	25-50	51+	Total
Drugfree	306	35.6%	42.5%	21.9%	100.0%
Tranquilizers	37	18.9	59.3	21.6	100.0
Ethanol	125	50.4	46.4	3.2	100.0
THC	47	66.0	34.0	0	100.0
Cocaine	10	80.0	20.0	0	100.0

	Sex Male	Female	Total
Drugfree	58.2%	41.8%	100.0%
Tranquilizers	54.1	45.9	100.0
Ethanol	76.0	24.0	100.0
THC	80.9	19.0	100.0
Cocaine	70.0	30.0	100.0

*Some drivers were in more than one substance group.

TABLE 14. - DISTRIBUTION OF MUTUALLY EXCLUSIVE DRUG GROUPS (Variable "SUBSAMPL")

Value (Driver Group)	n	%
Drugfree	306	61.9
LO BAC ONLY (Ethanol only, BAC = .01 - .09%)	16	3.2
HI BAC ONLY (Ethanol only, BAC $\geq$ .10%)	64	13.0
THC ONLY	19	3.8
TRANQ ONLY (Tranquilizers only)	20	4.0
ALCOHOL PLUS (Ethanol plus one or more other drugs)	45	9.1
OTHER POS (Other drugs and/or drug combinations)	24	4.9
Totals	494	100.0

ETOHOUT drivers. As noted earlier, probably-impaired drivers in the "out" group were identified from the police reports and the hospital records. Of all "out" drivers, 22.7 per cent were considered alcohol-involved, a figure similar to the 25.3 per cent alcohol-involved among the "in" drivers. This is probably coincidental, because undoubtedly there were impaired drivers not recognized as such by the police or hospital staff. The comparison of the figures does indicate, however, that the "in" sample was fairly successful in capturing alcohol-involved drivers.

Drug rates in accidents. While all the previous incidence rates were based on counts of drivers, some readers may be interested in substance involvement rates in accidents. Overall, 39.6 per cent of the accidents included one or more substance-involved drivers. As to the main substances, 26.5 per cent of the accidents involved alcohol, 10.0 per cent involved THC, and 7.8 per cent involved tranquilizers. (These numbers are not additive, for some accidents involved more than one substance.)

Summary. Altogether, 38 per cent of the drivers were found to have one or more substances in their blood, and the predominant groups were alcohol, cannabis (THC), and tranquilizers. Eleven per cent of the drivers had ingested multiple drugs, with the predominant combination being alcohol and something else. Males and younger people were overrepresented among drivers with alcohol and/or THC in their blood, while tranquilizers were found more frequently in drivers of ages 25 to 50.

Which Driver Groups Had the Highest Culpability Rates?

As noted in the Introduction, assessments of driver culpability in accidents can be used to indicate whether a substance is likely to increase crash risks. It may be hypothesized that the proportion of culpable drivers in a substance group will correlate positively with the relative crash risks of that group, as could be determined if exposure data as well as crash data were available.

If a substance-involved driver group does exhibit an elevated culpability rate, that could be due to (a) the substance, (b) the general accident propensities of the driver group, and/or (c) the conditions under which those drivers are on the road (exposure). Since factors (b) and (c) were not controlled in this study, the substance effects can only be suggested.

Assuring statistical independence. In multivehicle crashes, the driver of the first vehicle to create a dangerous situation is identified as culpable, so necessarily there can be only one culpable driver per accident. Thus, the culpability ratings of the drivers in multivehicle crashes are not statistically independent. This lack of independence must be accounted for if the driver sample includes more than one driver from some accidents. In this study, there were 22 accidents with two "in" drivers. To permit culpability comparisons among the various substance groups, a random numbers table was used to delete from the sample one driver from each of these accidents. Statistical tests requiring independent cases could then be performed.

(Similar deletions of the 22 drivers were made later in analyses of other dependent variables.)

Culpability in the main substance groups. To indicate that a substance may have played a causal role in the accidents, it is necessary (but not sufficient) to show that significantly more of the drivers in the substance group were judged culpable than were drivers in the drugfree group.

To show that a substance by itself has a possible impairing effect, drivers with only that substance in their blood need be compared with the drugfree drivers. These comparisons were made for the main substance groups, using Chi-square tests. The preferable comparisons are with the proportions of drivers judged fully culpable, because there is least ambiguity with those data. Next best is to also include those drivers judged culpable-or-contributory; these drivers had high responsibility for their crashes, and some may have been fully culpable. (This would be coded, for example, if the driver in a single-vehicle road departure accident claimed he was forced off the road by another vehicle, but there was no corroborating evidence.) Both kinds of comparisons are presented in Table 15, which show:

(1) The intoxicated drivers (BAC $\geq$ .10%) were much more frequently culpable than the drugfree drivers, a result with high statistical significance.

(2) The nonintoxicated alcohol-involved drivers had elevated culpability rates, but not to a statistically significant degree. (More on this shortly.)

(3) The marijuana (THC) drivers had elevated culpability rates, which reached statistical significance only when the culpable/contributory drivers were included.

(4) The tranquilizer driver group, while appearing somewhat less frequently culpable than the drugfree group, did not differ significantly from the latter.

(5) While the culpability rates for alcohol-plus-other-substance drivers differed significantly from the drugfree group, their culpability rates differed little from those of the low-BAC group. The data do not, therefore, indicate interaction or "synergistic" effects between alcohol and other substances. (Caution: the results may obscure such effects with specific substances and specific BAC levels.)

TABLE 15. - CULPABILITY RATES IN MUTUALLY EXCLUSIVE DRUG GROUPS

Substance Group	n	Fully Culpable %	Fully Culpable Signif.*	Culpable or Culp/Contrib. %	Culpable or Culp/Contrib. Signif.*
DRUGFREE	273	34.3%	--	42.5%	--
LOW BAC ONLY	13	53.9	N.S.	69.2	N.S.
HIGH BAC ONLY	61	73.8	$P < .001$	90.2	$P < .001$
THC ONLY	17	52.9	N.S.	76.4	$P < .05$
TRANQUILIZER ONLY	18	22.2	N.S.	33.3	N.S.
ALCOHOL PLUS	38	50.0	$P < .10$	73.7	$P < .001$
OTHER POSITIVE	24	45.8	N.S.	58.3	N.S.

*Chi-square tests compare substance groups with the drugfree group.

(6) The culpability levels for the "other-positive" group were higher than those for the drugfree, but the results were not statistically significant. Since this group was a heterogeneous mixture of non-alcoholic substances and substance-combinations, it may have included some definitely impairing drugs or drug combinations along with nonimpairing ones. It is unfortunate here that low incidence rates made it infeasible to examine the specific substances.

The fact that alcohol was found to have a possible impairing effect is not a new finding, but its consistency with studies measuring alcohol-associated crash risks gives credibility to the culpability analysis. With cannabis, on the other hand, previous evidence was extremely limited. Its high culpability rate here, combined with a similar finding among driver fatalities in Ontario (Warren et al., 1980), further suggests that cannabis may impair driving. The results for tranquilizers, however, raise doubts about the impairment effects of that drug. As to the "other-positive" group, the possibility of some significantly impairing drugs is suggested.

In subsequent analyses of culpability, only fully culpable drivers will be included unless otherwise specified.

Culpability and BAC levels. Table 15 showed that the culpability rate for the low-BAC drivers was not significantly different from that of the drugfree drivers, although the low-BAC group had a substantially elevated culpability rate. To provide more definite evidence on the relation of culpability to BAC, the alcohol-only drivers were divided into two groups: (a) those whose blood was sampled within two hours of their accident; and (b) those whose blood was drawn more than two hours after the accident. The BAC's of the first group presumably would reflect more closely the levels at the time of the accident,* while blood samples drawn later would probably underestimate the BAC's at the time of the accident.

*This wouldn't always be the case, however, for BAC's rise one to 1-1/2 hours after ingestion, hence the earlier-sampled drivers may actually have had lower BAC's at the time of the accident.

The results (Figure 9) show that within both groups, the culpability rates tend to increase gradually with BAC. The exception is the dip in culpability for each of the .15-.19% BAC groups. Presumably the dip is a random fluctuation easily occurring with the small numbers of drivers in the subgroups. It is unusual, however, for the dip to have occurred at the same BAC level among both the earlier and later sampled drivers. Note that for other than the .15-.19% BAC groups, the culpability rates were higher amongst the drivers sampled later, consistent with the idea that their BAC's at the time of their crashes were probably underestimated.

Although the statistical tests had previously failed to find statistical significance for the elevated culpability at low BAC's, the consistent results in Figure 9 support the inference that low BAC's increase crash risks. This, of course, had already been indicated in previous studies using exposure data, but it is encouraging to see that culpability analysis is also able to indicate milder impairment effects. The overall relationships in Figure 9 add to the credibility of culpability analysis.

Culpability among the ETOHOUTs. Among the 128 "out" drivers whom the police or hospital staff identified as having been drinking, 82.1 per cent were judged fully culpable. Although higher than the rates for alcohol-involved "in" drivers, this may have been due to the fact that "out" drivers were not interviewed. (Interview effects will be described shortly.)

Culpability and THC levels. Although the number of cannabis-only drivers was small and the culpability results were of inconsistent statistical significance, it is useful to see whether there is any evidence that driver THC level is related to culpability. In Table 16, the cannabis driver group is divided into two levels with about equal numbers of drivers in each. (The dividing line of .002 mcg/ml is of no known pharmacological significance.) As can be seen, the culpability rate of the lower THC group was hardly different from that for the drugfree. For the higher THC group, however, the culpability rate was a substantial 66.7%. That rate is approaching that of the alcohol-

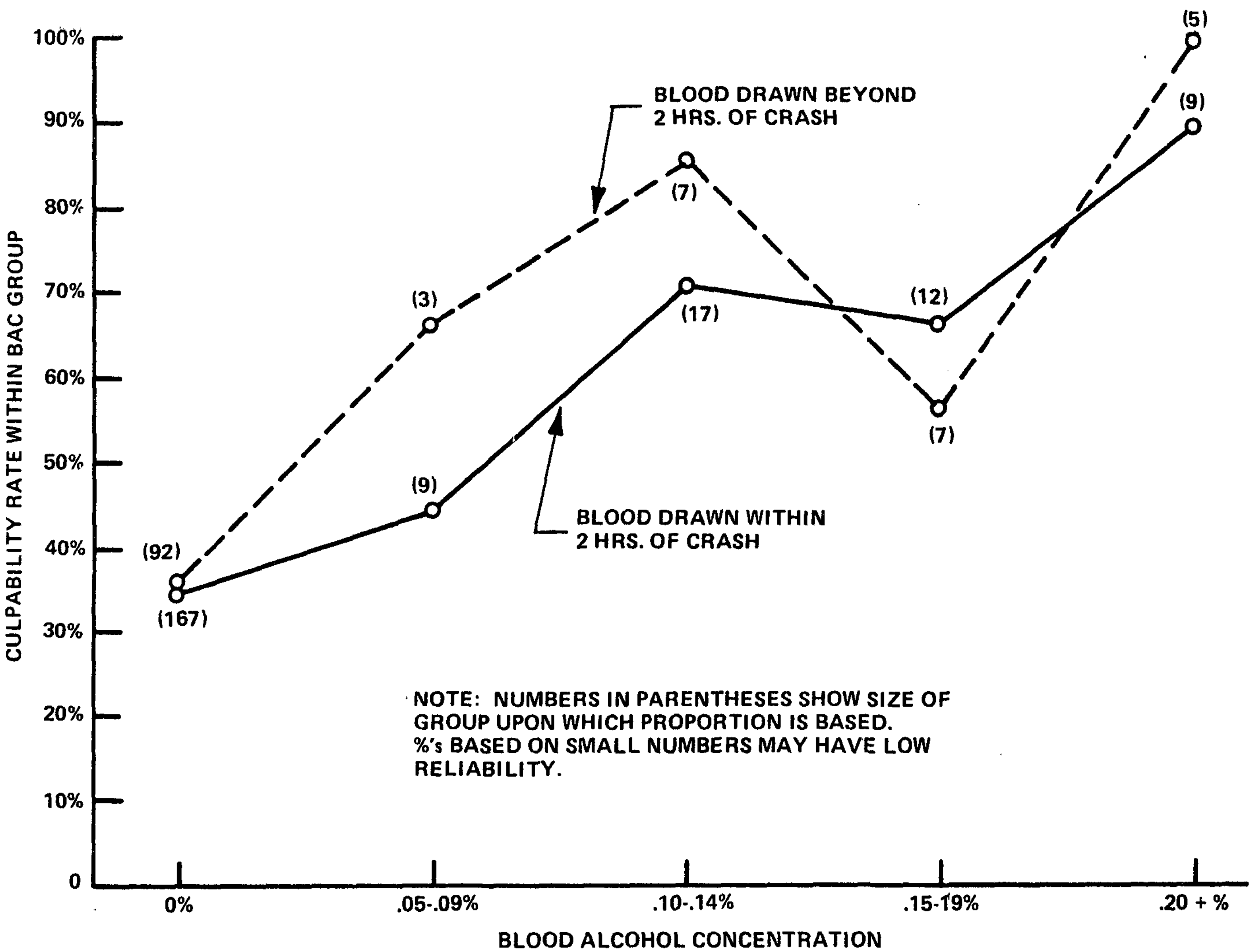

Figure 9 BAC's, CULPABILITY, AND TIME OF SAMPLING

intoxicated drivers (cf. Table 15). The possibility is suggested that these drivers had ingested marijuana shortly before their accidents.

TABLE 16. - THC LEVEL AND DRIVER CULPABILITY

Group	THC Level mcg/ml	# Drivers	Culpability Rate*	Signif.
DRUGFREE	0	273	34.3%	--
THC - ONLY	.001 - .002	8	37.5%	N.S.
	≥ .003	9	66.7%	P<.10

*Drivers judged fully culpable.

Culpability and diazepam levels. As noted in Chapter 5, concentrations of substances other than blood alcohol and THC were not statistically analyzed because the way to appropriately combine levels of parent drugs and metabolites is unclear. This problem obtains with respect to diazepam, for which the metabolite n-desmethyldiazepam is frequently found. Nevertheless, the question arises with regard to the low culpability rate found with diazepam and other tranquilizers as to whether they may have been due to low-level dosages. Since the Ontario driver fatality study (Warren et al., 1980) found high culpability among drivers in the tranquilizer-antidepressant group, it may be that dosage levels explain the differences in the results of the two studies.

Although we cannot deal adequately with the question of combining parent drugs and metabolites, nor do we know how to meaningfully compare blood levels of different drugs, we can at least see whether this study and the Ontario one differed in the levels of diazepam found in blood samples. (Diazepam was distinctly the most common tranquilizer found in both studies.)

Since the Ontario study did not distinguish drivers who had tranquilizers only in their blood, appropriate comparison may be made between the two studies only for drivers with evidence of diazepam regardless of other substances.* This is done in Table 17. It can be seen that there were somewhat more drivers in the Ontario study with higher diazepam levels. The differences could have contributed to the differential culpability findings in the two studies, although the differences do not seem large enough to have a pronounced effect.

Culpability and alcohol-drug combinations. Noted earlier was the finding that drivers who had evidence of alcohol and some other drug in their blood had a culpability rate no higher than that of the low-BAC drivers. These results could obscure, however, the effects of alcohol in combination with specific other drugs. Consequently, the culpability rates were determined for alcohol in combination with cannabis and tranquilizers respectively. Results were as follows:

Alcohol plus:	# Drivers	Fully Culpable	Signif.	Culpable or Culp/Contrib
Cannabis	22	45.5%	N.S.	77.3%
Tranquilizer	8	62.5%	N.S.	75.0%

The significance tests have compared each group with the drugfree group (cf. Table 15). Neither culpability rate was significantly different than that for the drugfree group, though both rates were higher than in the drugfree group. The tranquilizer-alcohol combination was the highest, falling between that reported for the low-BAC-only and high-BAC-only groups (Table 15). With such small numbers of cases, the results must be considered inconclusive. Though they do not suggest a synergistic impairment effect when alcohol is combined with marijuana or tranquilizers, a more definite conclusion must await a larger study with necessary controls.

*The Ontario findings in urine specimens were ignored here, since our study did not analyze urine content.

TABLE 17. - DIAZEPAM LEVELS FOUND IN THIS STUDY AND AMONG ONTARIO DRIVER FATALITIES

(All drivers in whom diazepam or diazepam metabolite were found in blood samples.)

Diazepam Level - mcg/ml	This Study n	This Study %		Ontario Study** n	Ontario Study** %	
0* - .05	15	48.4		6	37.5	
.06 - .10	4	12.9		2	12.5	
.11 - .20	5	16.1	38.7%	3	18.8	50.0%
.21 - .40	4	12.9		4	25.0	
.41+	3	9.7		1	6.2	
	31	100.0%		16	100.0%	

*Some drivers had no diazepam but diazepam metabolite in blood.

**Counts made from the data in Cimubra et al., 1980.

Culpability with controls for age and sex. Earlier in this chapter it was shown that alcohol and cannabis were found mostly among young male drivers, while tranquilizers were more common among middle-aged drivers. This raises the prospect of confounding, for culpability rates may vary by age and sex. Table 18 reveals the possibility for such confounding by examining culpability within the drugfree drivers. The table shows that the culpability rate was only slightly higher for female than for male drivers, which indicates that sex confounding was unlikely to be much of a problem. Age, however, could be confounding, for there were much higher culpabilities among the youngest and the oldest drivers. Thus, youthfulness could help to explain the higher culpability rates of the alcohol-and marijuana-involved drivers, while the lower culpability of the tranquilizer group could be due in part to their middle-age status.

To control for age, the drivers were divided into age groups that provided categories that were relevant and with sufficient numbers of cases for most comparisons. The age categories were: under 21, 21-30, 31-64, and over 64 (elderly). Wherever numbers were adequate, the substance-involved drivers were compared with drugfree drivers within age-sex combinations. Many comparisons were not possible e.g. alcohol and drug involvement was so rare among the elderly that substance culpability rates could not be determined for that group.

Table 19 presents the results of the comparisons including some where numbers were insufficient to perform valid Chi-square tests. Few tests could be made for the marijuana and tranquilizer groups because of the small numbers. While limited, the results were consistent with previous indications.

(a) In every comparison regarding alcohol, the culpability rates for the alcohol-involved were substantially higher than for the drugfree drivers; where the groups were large enough, the differences were statistically significant.

(b) For the comparisons with marijuana-involved drivers, their culpability rates were substantially higher than that of the drugfree drivers; while limited to only one independent test, statistical significance was indicated.

TABLE 18. - AGE AND SEX IN RELATION TO CULPABILITY AMONG DRUGFREE DRIVERS

		n	% Fully Culpable
Sex			
	Men	157	32.5%
	Women	116	37.1
Age			
	Teens	48	47.9%
	20 - 29	110	28.2
	30 - 39	33	30.3
	40 - 49	24	33.3
	50 - 59	30	30.0
	60 - 69	15	26.7
	70+	14	64.3

TABLE 19. - CULPABILITY AND DRUGS, WITH CONTROLS FOR DRIVER AND AGE AND SEX

	Substance-Involved		Drugfree		
	n	Culp. Rate	n	Culp. Rate	Statistical Signif. of Diff.*
Alcohol-only					
Males under 21	15	73.3%	25	56.0%	N.S.
Males 21-30	18	66.7%	66	27.3%	$P < .01$
Males 31-64	22	72.7%	51	23.5%	$P < .01$
Females under 21	4	100.0%	20	40.0%	**
Females 21-30	11	54.5%	43	32.6%	N.S.
[M & F under 21	19	78.9%	45	48.9%	$P < .05$]***
Marijuana-only					
Males 21-30	9	66.7%	66	27.3%	$P < .05$
[M & F 21-30	12	58.3%	109	29.4%	$P < .05$]***
Tranquilizers-only					
Males 31-64	5	0%	51	23.5%	**
Females 31-64	8	25.0%	45	31.1%	**
[M & F 31-64	17	17.6%	206	27.1%	N.S.]***

*Chi-square tests compared the substance-involved and drugfree groups.
**Numbers involved in group were too small for valid Chi-square test.
***Caution: Tests of males and females combined are not independent of tests of males and females separately; they were included to provide comparisons based on larger numbers.

(c) In every comparison of the tranquilizer-involved drivers, their culpability rates were somewhat less than for the drugfree drivers, though the differences were not statistically significant.

From these results, it seems safe to conclude that the relative culpability rates of the substance groups cannot be attributed wholly to the age or sex of the substance users (although age and sex may influence the culpability rates).

Culpability and control for number of crash drivers. Since the culpability analyses appear useful for suggesting the impairment effects of substances, it is important to check on any possibilities that would call the validity or meaning of the findings into question. One possibility is that the culpability ratings do little more than reflect the number of single-driver accidents within a substance group. This could arise from the fact that the drivers in single-driver accidents* are usually judged fully culpable. In this study, 77.4 per cent of these drivers were so judged, and another 15.2 per cent were judged either culpable or contributory. The latter were often drivers who claimed another vehicle forced them off the road, but there was no evidence to support or refute the driver's claim.

To see whether the culpability analysis does more than just reflect the proportions of single-driver accidents, the culpability rates for the various SUBSAMPL groups were determined for the subgroup of drivers in multiple-driver crashes. There were 303 such drivers with culpability data. Table 20 shows that, as expected, the exclusion of single-driver crashes lowered the culpability rates in all the SUBSAMPL groups (compare with Table 15). Nevertheless, the order of the groups remains relatively unchanged, and the alcohol-intoxicated and marijuana drivers have fairly high culpability rates. The one

*The reader is reminded that these are usually single-vehicle accidents, but a moderate number of crashes involving a driverless parked vehicle are also included in single-driver crashes.

group whose standing was changed radically is the low-BAC drivers; none was judged culpable in multiple-driver crashes. This means that all of the low-BAC drivers previously judged culpable were in single-driver crashes, and excluding those drivers "washes out" the culpability findings. This does not mean that low-BAC drivers were not culpable, but rather that their culpability was wholly a reflection of their involvement in single-driver crashes. For all the other groups it may be concluded that involvement in single-driver crashes only partly (or even slightly) explains their culpability rates. Thus, culpability is shown to indicate something more than involvement in single-driver crashes.

TABLE 20. - CULPABILITY RATES IN THE "SUBSAMPL" DRIVERS IN MULTIPLE-DRIVER CRASHES

Substance Group	n	Culpability Rate
DRUGFREE	226	24.3%
LOW BAC ONLY	5	0%
HIGH BAC ONLY	18	66.7%
THC ONLY	11	45.5%
TRANQUILIZER ONLY	15	13.3%
ALCOHOL PLUS	13	30.8%
OTHER POSITIVE	16	37.5%

Culpability and control for interviews. A mischievous problem for culpability analysis was created by the fact that over a third of all the drivers in the crashes of the "in" drivers were not interviewed. To test the hypothesis that an interviewed driver may tend to avoid blame for his accident, the culpability ratings of all "in" drivers who were and were not interviewed were compared. Results were as follows:

Drivers interviewed - 37.5% culpable

Drivers not interviewed - 59.6% culpable

These data suggest that biases could be created if there were substantial differences in the interview rates of the substance groups. The data below show that there were such differences.

TRANQUILIZER ONLY	-	83.3%	interviewed
THC ONLY	-	81.3%	"
OTHER POSITIVE	-	79.2%	"
DRUGFREE	-	78.5%	"
LOW BAC ONLY	-	76.9%	"
HIGH BAC ONLY	-	63.9%	"
ALCOHOL PLUS	-	63.2%	"

These differences are troublesome, because the high interview rate could help produce the low culpability rate for the tranquilizer group, while the low interview rates could be partially responsible for the high culpability rates of the alcohol-involved groups. Consequently, the comparisons among the SUBSAMPL groups require controlling for whether the driver was interviewed or not. This is done in Table 21. In every case the culpability rates were higher for the drivers not interviewed. The important point is, however, that <u>when controlling for interviews, the relative ordering of the substance groups remains virtually the same.</u> A major exception is the 66.7% culpability rate of drivers who had ingested tranquilizers and were not interviewed; since there were only three such drivers, little meaning can be imputed to the statistic.

The import of this analysis is that the <u>absolute</u> magnitude of the culpability rates is called into question because of a possible bias effect, but the <u>relative</u> <u>standing</u> of the substance groups is not. Possibly the interview rates of the substance groups may be used to produce "corrected" culpability rates, but such adjustments could themselves be called into question. While it may be true that drivers not interviewed were sometimes judged culpable because they weren't able to "defend" themselves, it is also possible that culpable drivers tend to be less <u>available</u> for interviews; they may move more often, be less likely to own phones, or be more inclined to refuse interviews

TABLE 21. - CULPABILITY RATES IN THE "SUBSAMPL" DRIVERS, CONTROLLING FOR INTERVIEWS

	Drivers Interviewed		Drivers Not Interviewed	
	n	Culp. Rate	n	Culp. Rate
DRUGFREE	215	30.7%	59	47.5%
LOW BAC ONLY	10	50.0%	3	(66.7%)*
HIGH BAC ONLY	39	66.7%	22	86.4%
THC ONLY	13	53.8%	4	(50.0%)*
TRANQUILIZER ONLY	15	13.3%	3	(66.7%)*
ALCOHOL PLUS	24	41.7%	14	64.3%
OTHER POSITIVE	19	42.1%	5	(60.0%)*

*%'s based on small numbers cannot be considered reliable.

about their accidents. If this is true, adjustment of the data to compensate for interview status might result in underestimating culpability rates. The safest approach may be simply to control for interview status, as was done here.

Summary and discussion. This section examined the basic issue of whether the presence of a substance in a driver's blood is likely to significantly impair him so as to increase his chances of an accident. Those chances weren't measured directly, of course, but ordering driver substance groups by their culpability rates is assumed to correlate with the relative crash risks of those groups. Besides substance impairment, however, culpability rates may be affected by driver attributes and exposure factors, as will be discussed shortly.

In addition to the results for alcohol-involved drivers, it was found that marijuana-involved drivers had elevated culpability rates, and culpability appears to increase with the concentration of tetrahydrocannabinol in the driver's blood. Drivers who had ingested tranquilizers had culpability rates not significantly different from the rates of drugfree drivers.

Alcohol in combination with other substances did not yield culpability rates much different than alcohol by itself. The subsample sizes were too small, however, to suggest whether specific levels of alcohol and other substances in combination would have synergistic impairment effects.

The general results were re-examined with controls for driver age and sex, the number of single-driver crashes in a substance group, and driver interview status. These reexaminations generally supported the relative culpabilities associated with alcohol, marijuana, and tranquilizers.

It is important to close this section with reminders of the limitations of the culpability analysis. Any group of substance users may have special attributes or personality characteristics that distinguish them from nonusers. We have seen that alcohol, marijuana and tranquilizers were found more frequently among certain age and sex groups. There may be other qualities that distinguish the substance users. We found, for example, that the alcohol-involved drivers were generally less available for telephone interviews than others. This was not just because they refused cooperation (a minor problem - cf. Table 2), but because they had no phone listed or their phones weren't answered. Perhaps many cannot afford phones, perhaps others are "on the go" a great deal. Regardless of what these phenomena mean, they suggest that the alcohol-involved drivers in this study are probably atypical in various ways. In general, people who become intoxicated on alcohol, marijuana, cocaine, or other recreational drugs are probably less conservative and less conventional than nonusers, and those who willingly drive while intoxicated are probably a different breed again. In addition, individuals using antianxiety, antidepressant, and other psychoactive drugs for their problems may represent a special population. Whatever atypical characteristics substance users or abusers may have could influence their crash risks. As Warren and colleagues (1980) observed, separation of group characteristics from the effects of substances is a problem extremely difficult to solve.

As noted earlier, differential exposure to driving conditions by the driver groups could also affect the culpability rates. For example, the tranquilizer group may have had a low culpability rate if those drivers were on the road at less hazardous times and places than the other groups. While exposure data were not obtained in this study, later chapters will show that crash circumstances did vary across substance groups.

One gains some confidence that substance impairment effects were being reflected when BAC's and THC levels appeared positively related to culpability rates. These relationships do not rule out the effects of driver attributes or exposure, but they do at least make substance effects seem more plausible.

What Kinds of Collisions Did the Substance-Involved Drivers Have?

Having found that alcohol and/or marijuana were associated with elevated culpability rates, we next consider the question of how those substances might impair drivers. In this section we determine whether substance-involved drivers are overrepresented in particular types of collisions, which may provide clues as to forms of impairment. The Introduction noted that previous studies found certain collision types to be associated with alcohol. Single-vehicle collisions predominate in the crashes of drinking drivers, but evidence for other types was more ambiguous. The analysis here should reduce some of that ambiguity, while also examining collision types of cannabis-involved drivers.

While the purpose of this section is to suggest kinds of impairments, the necessity for inference should be clearly understood. The data for making those inferences will be presented, so the reader will be free to make his or her own interpretations.

Introducing CALAX1R and SMPCALAX. The CALAX1 coding scheme, with its 43 collision types, is too detailed for a clear analysis involving only eighty alcohol-only drivers and twenty marijuana-only drivers. Consequently, a collapsed eleven-category collision type scheme, called CALAX1R, was made by combining types from CALAX1. An even further simplification, SMPCALAX, reduces the CALAX1 system to only six collision types.* These two systems are described in Tables 22 and 23.

In these two reduced taxonomies, some question may arise as to the kind of collisions that would be categorized as "other". Not only does this category include certain unusual accidents (e.g. a motorcycle hitting a pothole and falling over) but also those where the role of the individual vehicle cannot be identified (e.g. a head-on crash where it cannot be determined which vehicle was the striking one and which was the struck or "victim" vehicle).

*CALAX2 and CALAX3 could not be used as the simpler systems, for those two versions type the entire accident configuration in two-vehicle impacts, without identifying the role of specific vehicles.

TABLE 22. - CALAXIR COLLISION TYPES

Type Label	Collisions Included	CALAX No's.*
a. Single-driver forward impact	Hit-stationary-object; hit parked vehicle; end departure	121,122,124
b. Side departure passive	Simple roadside departure.	111
c. Side departure active	Out-of-control & "phantom vehicle".	112,113
d. Rear end strike	Rear vehicle in overtaking collision, incl. same-direction sideswipe	211,213,215 217,221
e. Opp. direction strike	Striking vehicle in head-on collision or opp.-direction sideswipe	311,321
f. Turn-into-path	Merging collisions; turning into paths of oncoming vehicles.	421-428
g. Turn-across path	Left turn before oncoming vehicle.	411-416
h. Intersecting paths	Cross-path intersection collisions	511
i. Rear end struck	Forward vehicle in overtaking collision, incl. same-direction sideswipe	212,214,216 218,222
j. Opp. direction struck	"Victim" vehicle of head-on or opposite-direction sideswipe	312,322
k. Backing	Any-backing collision	611,612
l. Other	"Freak" accidents; rear-end, head-on accidents where struck, striking unknown.	118,223,313 323,711,996

*Numbers refer to types in Figure 8.

TABLE 23. - SMPCALAX COLLISION TYPES

Type Label	Types Included (From CALAX1R)
Single driver	a, b, c
Rear-end strike	d
Opposite-direction strike (incl. head-on)	e
Interacting paths	f, g, h
"Victim": rear-end, head-on	i, j
Other	k, l

Collision types among the SUBSAMPL drivers. Table 24 compares collision types of all the alcohol-involved driver groups, including the nurse-or-police-identified ETOHOUT drivers, with the drugfree drivers. As might be expected, the collision type distributions of the alcohol-involved groups resemble each other, and on the whole their crashes differ from those of the drugfree drivers. A few highlights should be noted.

(1) The collision type distinctly prominent among the alcohol-involved is the passive roadside departure (b), where the driver simply drove off the road. The active roadside departure (c), where the vehicle appears to have gone out of control, is considerably less prevalent. This collision type is, however, most prominent among the high-BAC and alcohol-plus-drug groups, possibly indicating a special impairment effect among these drivers. Both road departure types were infrequently found among the crashes of drug-free drivers. The results suggest that reduced alertness and reckless driving may both be special problems of the alcohol impaired, but reduced alertness may be the far more salient problem.

(2) The low-BAC drivers appear somewhat different from the other drinking drivers, although the smaller size of the group (13) makes the percentages less reliable. (A more detailed examination of collision types in relation to BAC will be provided later.)

(3) Ignoring the low-BAC group, the alcohol-involved drivers were more frequently than the drugfree in the striking (rear) vehicle of rear-end crashes, and less often in the struck vehicle within such crashes. The drinking drivers, especially the ETOHOUTs, were more frequently in single-driver forward impact crashes, a type which involves mostly collisions with parked vehicles. Together, these patterns suggest gross perceptual failure as a problem of the alcohol-impaired driver.

(4) The high-BAC and ETOHOUT drivers were more often in the striking vehicle of opposite-direction (head-on) crashes than were the drugfree, and

TABLE 24. - CALAXIR COLLISION TYPES OF ALCOHOL-INVOLVED DRIVERS IN COMPARISON WITH DRUGFREE DRIVERS

CALAXIR Collision Type	Drug-free	Lo BAC only	Hi BAC only	Alcohol plus	ETOH-OUT*
a. Single-dr. Forward	3.2	7.7	6.6	7.5	13.0
b. Side dep. passive	10.3	53.9	42.6	40.0	46.3
c. Side dep. active	3.2	0	18.0	15.0	8.1
d. Rear end strike	8.5	0	14.8	10.0	8.9
e. Opp. direction strike	1.8	0	4.9	0	2.4
f. Turn-into-path	11.4	0	1.6	5.0	5.7
g. Turn-across-path	15.0	23.1	3.3	2.5	4.1
h. Intersecting paths	18.5	0	0	12.5	4.9
i. Rear end struck	15.0	0	0	2.5	1.6
j. Opp. dir. struck	6.4	7.7	0	0	0
k. Backing	0.7	0	4.9	0	0.8
l. Other	6.0	7.7	3.3	5.0	4.1
Total %	100.0%	100.0%	100.0%	100.0%	100.0%
Total drivers	281	13	61	40	123
#Type unknown	11	1	1	3	5

*Alcohol-involvement of this group based on police/hospital judgment only.

the drinking drivers were much less in the struck ("victim") vehicle within such collisions. (Of the 237 alcohol-involved drivers represented in Table 24, only one, a low-BAC driver, was in a head-on "victim" vehicle. Eighteen of the 281 drugfree drivers were such "victims.")

(5) Common collision types of the drugfree were turn-into-path, turn-across-path, and intersecting path collisions. These all are accident types where interacting vehicle paths presented hazards to the drivers, in marked contrast with the road departure crashes prominent among the alcohol-involved. Caution - Such data should not be interpreted to mean that drunk drivers are less at risk in interacting-path situations, nor that drugfree drivers find those situations more troublesome than do impaired drivers. It is more reasonable to infer that since drugfree drivers are far less likely to be involved in road-departure crashes and other reduced-alertness types, the crashes they do have will more commonly result from the hazards of interacting vehicle paths.

Turning to the collision types involving substances other than alcohol, these are shown in Table 25. Again the drugfree group is shown for a standard of comparison. Regarding the three substance groups of drivers shown, it must be understood that the proportions for any one collision type may have low reliability with such small subsamples. Hence, inferences based on small differences among any of the groups are not justified. As can be seen in Table 25, there are in fact no large differences among any of the three substance groups, nor do they differ much from the drugfree drivers in their collisions. In contrast with the alcohol-involved groups, these drivers had few single-driver crashes (types a, b, c). The most prominent collisions among these drivers are the turn-into-path, turn-across-path, intersecting path, and rearend "victim" collisions.

The group of particular concern is the marijuana-involved, since previous analyses revealed elevated culpability rates among these drivers. Although they exhibit slight prominence of active (out-of-control) road

TABLE 25. - CALAX1R COLLISION TYPES INVOLVING SUBSTANCES OTHER THAN ALCOHOL

CALAX1R Collision Type	Drug-free	THC only	Tranq. only	Other positive
a. Single-dr. forward	3.2	5.9	0	8.3
b. Side dep. passive	10.3	0	5.3	8.3
c. Side dep. active	3.2	11.8	5.3	4.2
d. Rear end strike	8.5	5.9	5.3	8.3
e. Opp. direction strike	1.8	0	0	4.2
f. Turn-into-path	11.4	17.6	15.8	8.3
g. Turn-across-path	15.0	17.6	10.5	16.7
h. Intersecting paths	18.5	5.9	21.1	12.5
i. Rear/end struck	15.0	17.6	26.3	12.5
j. Opp. dir. struck	6.4	0	5.3	4.2
k. Backing	0.7	0	0	4.2
l. Other *	6.0	17.6	5.3	8.3
Total %	100.0%	100.0%	100.0%	100.0%
Total drivers	281	17	19	24
#Type unknown	11	1	0	0

Caution: Proportions based on small numbers may have low reliability.

*"Others" include such accidents as head-on crashes where it was not possible to determine which was the striking vehicle, or a motorcycle falling over when hitting a pothole.

departure accidents, the turn-into-path type and the turn-across-path type, these appear simply to be tendencies of young male drivers*. If there are subtle "cannabis collision types," their detection may require a larger sample and use of a highly detailed collision type system, like CALAX1.

Although the tranquilizer-only drivers had a very low culpability rate, the question may arise as to whether the outstanding proportion of rearend-struck collisions in this group (Table 25) may not result from excessively slow or sluggish driving by the tranquilized, making them more prone to being hit from behind. This hypothesis is not tenable, for the rearend-struck situation is characteristic of even drugfree drivers in the middle-age group.*

Unfortunately, statistical tests for the significance of differences among groups cannot be made with the data of Tables 24 and 25, for the cell frequencies are just too small. To provide cell sizes that make the computations of Chi-square justifiable, the low-BAC and high-BAC groups were combined, and the collision types were represented with the SMPCALAX system. The results are shown in Table 26. There the basic similarities of the alcohol groups are apparent, and all differed significantly from the collisions of drugfree drivers. On the other hand, none of the other substance groups had collisions differing significantly from those of the drugfree drivers.

Collision types and BAC level. The relation of BAC to collision types is useful to suggest whether the form of impairment varies with BAC. To examine this matter, the collision types of alcohol-only drivers were divided into BAC groups. Despite small subgroups, the results are suggestive.

*From data on collisions, age, and sex among drugfree drivers. (Data not presented here.)

TABLE 26. - SMPCALAX COLLISION TYPES WITHIN SUBSTANCE GROUPS

Collision Type	Alcohol only	Alcohol plus	ETOH OUT*	Drug-free	THC only	Tranquilizer only	Other pos.
Single Driver	66.2%	62.5%	67.5%	16.7%	17.7%	10.5%	20.8%
Rearend, striking vehicle	12.2	10.0	8.9	8.5	5.9	5.3	8.3
Head on, striking vehicle	4.1	0	2.4	1.8	0	0	4.2
Interacting paths (angle, turning, merging)	8.1	20.0	14.6	45.0	41.1	47.4	37.5
"Victim" veh., rearend/ headon	1.4	2.5	1.6	21.3	17.6	31.6	16.7
Misc.	8.1	5.0	4.9	6.7	17.6	5.3	12.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
n (drivers)	74	40	123	281	17	19	24

Significance levels: substance groups vs. drugfree

P< .01 N.S.

P< .01 N.S.

P< .001 N.S.

*Alcohol-involvement of this group based on police/hospital judgment only.

There were neglible differences among positive-BAC groups in regard to most collision types, including head-ons and rear-ends, in which the numbers were very small. However, the few that exhibited interesting relationships are shown in Figure 10. The following are noteworthy points in the figure.

(1) Relevant to Question 4 in the Introduction, both active ("out of control") and passive (drive off road) roadside departure accident types increased and then decreased with BAC. The passive roadside departures were most prominent at .05-.09% BAC, while the active roadside departures peaked just above that level. By inference, this suggests that inattention may first become a driving problem at "Had Been Drinking" levels, while recklessness and speeding may be most manifested among those who have just entered the "Driving While Intoxicated" zone. The few active roadside departures at BAC's greater than .20% suggests that recklessness and speeding may not be a major factor at such high levels of inebriation.

(2) The single-driver forward impacts (mainly hit-parked-vehicle crashes) and backing-plus-miscellaneous types, though never highly pronounced, reached their highest levels at BAC's beyond .20%. While the miscellaneous crashes are ambiguous, the backing and single-forward crashes suggest gross perceptual failure.

It may also be noted that Table 24 showed the single-driver-forward-impact crashes to be <u>most</u> pronounced and the active road departure less pronounced among the ETOHOUT's. These were the "out" drivers whose alcohol involvement was noted by the police and/or hospital staff. If very high BAC's are especially represented among those with manifestly observable intoxication,* these results may partially support those in Figure 10.

*Chapter 7 will in fact show that police and nurses are more likely to detect alcohol-involvement at very high BAC's.

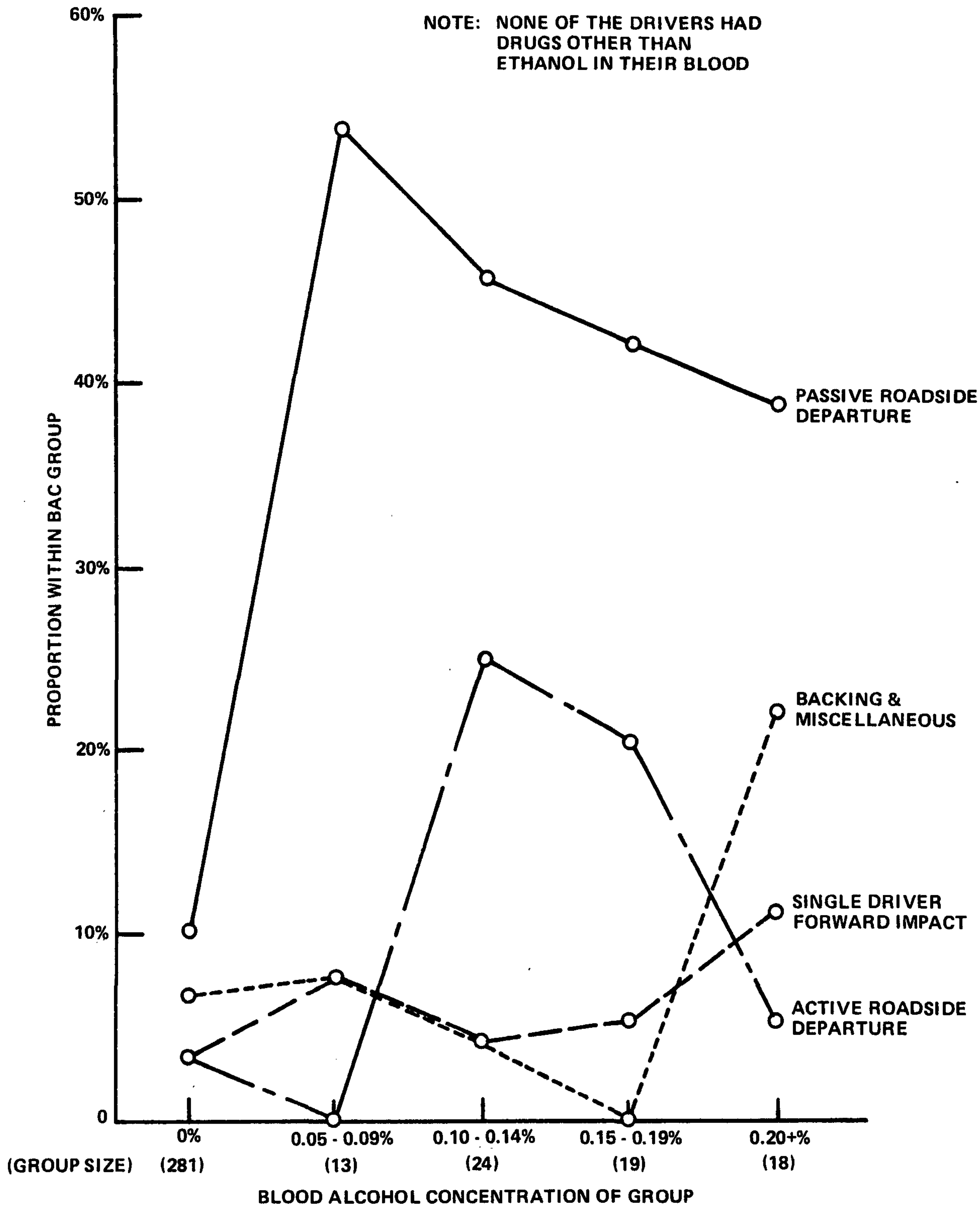

Figure 10 **KEY COLLISION TYPES IN RELATION TO BAC**

Clarifying the alcohol collision types. Although the distribution of collision types among the alcohol-involved drivers differs significantly from the distribution among the drugfree drivers, the results as presented so far do not show clearly whether any collision type other than the single-driver kind represent distinctly alcohol-associated crashes. Part of the problem lies in the fact that single-driver crashes are so predominant among the alcohol-impaired, that all other types are reduced to small proportions. To show more clearly which collision types are most alcohol-associated, we can answer the question: In which collision types were alcohol-involved drivers most represented? To find the answer, we determine the proportion of alcohol-involved drivers within each collision type. Since the collisions of the alcohol-only and alcohol-plus groups were similar, they may be combined to provide a complete sample of the alcohol-involved. This was done to determine the proportion of drinking drivers in each collision type, shown in Table 27.

The collision types in Table 27 are ordered by their proportion of alcohol-involved drivers. Those at the top of the list qualify as "alcohol collision types," while those toward the bottom least qualify. Notice how the results show more clearly than before those collision types in which alcohol is prominently involved. The collisions have been divided into three groups within each of which the proportions of drinking drivers are clearly separated from the others. Roadside departure crashes seem to be the alcohol collision type par excellence. The next three types, while not as distinctly associated with alcohol, have proportions of drinking drivers that are definitely pronounced. They include hitting-parked-vehicle crashes and the striking vehicle in head-on and overtaking accidents. While these types comprised only small proportions of all alcohol-involved crashes, their connection with alcohol seems clear. Especially impressive are the differences in alcohol involvement between the opposite-direction-strike, the rear-end strike, and their "victim"-vehicle counterparts.

While the proportions in Table 27 suggest the relative effects of alcohol impairment, it is important to remember that high proportions of alcohol involvement may result if drinking drivers are highly exposed to particular circumstances which in turn tend to produce certain kinds of collisions.

TABLE 27. - ALCOHOL INVOLVEMENT WITHIN CALAXIR COLLISION TYPES

Collision Type	(1) Total Drivers with Type	(2) Alcohol-Involved Drivers*	(3) Proportion Alcohol-Involved (2)÷(1)	
Side departure passive	81	49	60.5%	High
Side departure active	30	17	56.7%	
Single-dr. forward	20	8	40.0%	Medium
Opposite-direction strike	9	3	33.3%	
Rear-end strike	41	13	31.7%	
Turn-across-path	57	7	10.5%	Low
Intersecting Path	65	5	7.7%	
Turn-into-path	43	3	7.0%	
Opposite-direction struck	21	1	4.8%	
Rear-end struck	54	1	1.9%	
(Backing	6	3	50.0%)	
(Other	28	5	17.9%)	
ALL TYPES	494	125	25.3%	

*Drivers with any alcohol, without regard to presence/absence of other substances.

Clarifying rear-end collisions. Table 27 supported the view that a rear-end-strike collision is one in which alcohol-impaired drivers tend to be found. To be sure, this is not one of the most prominent alcohol collision types, but as Question 5 in the Introduction suggested, it may be possible to learn more about alcohol impairment by examining particular kinds of rearend collisions. CALAX1 distinguishes three kinds of rear-end-strikes, as follows:

(a) #211 - Rear vehicle runs into stopped vehicle ahead, e.g. at a stoplight.

(b) #213 - Rear vehicle overtakes and impacts a slower vehicle ahead.

(c) #215 - A vehicle collides with one it is following when the lead vehicle decelerates, e.g. a "tailgating" collision.

Since there were relatively few rear-end strikes, it was necessary to examine these crash types among all alcohol-involved drivers, regardless of their involvement with any other drugs. The ETOHOUT and drugfree drivers were also examined for comparison. The results in Table 28 were surprising, for they showed that the drugfree rear-end-strikes nearly always involved an impact with a stopped vehicle (CALAX1 #211), while the alcohol-involved drivers had proportionately more overtaking collisions with a slower lead vehicle (CALAX1 #213). Thus, it seems that drugfree rear-end-strikes resulted mainly from inattention, while the alcohol-impaired drivers had problems with inattention and with speed-distance misjudgments in overtaking slower vehicles. Such speculative interpretations should be taken cautiously, especially since they are based on very small numbers.

Summary. The only substance group found to have distinctive collision types was the alcohol-involved one. Among high-BAC, low-BAC, and alcohol-plus drivers, single-driver crashes were far more common than among the drugfree drivers. The single-driver crashes were typically road departures, in which the driver simply drove off the side of the road. Other types which were less pronounced but still clearly "alcohol collision types" involved the striking

TABLE 28. - REAR-END COLLISIONS OF ALCOHOL-INVOLVED AND DRUGFREE DRIVERS

	Driver Group		
CALAXI Type	Drugfree	Alcohol-involved	ETOHOUT
#211 - Hit stopped vehicle	92.0% (23)	45.5% (5)	57.1% (4)
#213 - Hit slower vehicle	0% (0)	45.5% (5)	28.6% (2)
#215 - Hit decelerating vehicle	4.0% (1)	9.1% (1)	0% (0)
#217 - Hit forward vehicle, situation unknown	4.0% (1)	0% (0)	14.3% (1)
Total rear-end strikes	100.0%	100.0%	100.0%
	(25)	(11)	(7)

Caution: Proportions based on small numbers may have low reliability.

vehicle in head-on, rear-end and related sideswipe crashes. Such types suggest that alcohol impairs driver alertness, attentiveness, and perhaps tracking abilities. Active road departures, which suggest speeding and reckless driving, became pronounced only at intermediate BAC levels. Finally, certain rearend crashes of the alcohol-involved point to problems of speed-distance judgments.

Drivers having ingested marijuana only, tranquilizers only, or some other non-alcohol drug were involved in collision types at rates not statistically different from the drugfree rates.

7. RESULTS SPECIALLY FOCUSING ON ALCOHOL

The scope and seriousness of alcohol as a highway safety problem warrants comprehensive analyses to provide the kind of information needed to design countermeasures. Since there was a substantial number of alcohol-involved drivers in the study, it is possible to further examine the circumstances of their accidents. This is especially helpful for identifying situations in which the impaired driver seems to have particular problems.

Much of this chapter concentrates on circumstances of accidents. In addition, the determination of alcohol involvement from behavioral clues will also be examined.

What Are the Special Circumstances of the Alcohol-Involved Accidents?

As noted in the Introduction, many studies have found that the circumstances of drunk-driver crashes differ in several respects from those of sober drivers. It is important to take at least a brief look at circumstances in this study to see if the alcohol crashes represent a typical or deviant sample, and also to see if any new discovery about circumstances may be made.

Table 29 summarizes the results for all the additional circumstance variables examined in this study. (Age and sex were presented earlier.) Each variable is discussed below.

Environment. No significant differences were found in the general rural-suburban-urban location of the crashes of alcohol-involved and drugfree drivers. As noted earlier in the report, the sample accidents occurred mainly in the Rochester Metropolitan area.

TABLE 29. - CRASH CIRCUMSTANCES OF ALCOHOL-INVOLVED AND DRUGFREE DRIVERS

	Driver Group*			
	Drug free		Alcohol only	
Environment	N	%	n	%
Urban	142	48.6	38	50.0
Suburban	142	48.6	37	48.7
Rural	8	2.7	1	1.3
Total	292	100.0	76	100.0
Signif. of diff.		N.S.		
Land Use				
Residential	103	41.0	42	64.6
Business/manufacturing	76	30.3	12	18.5
Res. & bus./mfg.	59	23.5	8	12.3
Other, e.g. agric.	13	5.2	3	4.6
Total	251	100.0	65	100.0
Signif. of diff.		P < .01		
Road Horizontal Alignment				
Straight	245	88.0	47	66.2
Left curve	11	4.0	15	21.1
Right curve	12	4.3	5	7.0
Curve, direction unknown	10	3.6	4	5.6
Total	278	100.0	71	100.0
Signif. of diff.		P < .001		
Intersections				
Intersection-related	139	52.3	26	40.0
Not intersection	108	40.6	37	56.9
Driveway/alley	19	7.1	2	3.1
Total	266	100.0	65	100.0
Signif. of diff.		P < .05		

*Based on 293 drugfree and 76 alcohol-only drivers. Unknowns omitted from tables.

(Continued)

TABLE 29. (Continued)

Road Type	Drug free n	Drug free %	Alcohol only n	Alcohol only %
Lim. access/divided	24	8.2	11	14.7
Other multilane	108	36.9	16	21.3
2-lane, 2-way	102	34.8	29	38.7
One-way	3	1.0	1	1.3
Road, type unk.	31	10.6	12	16.0
Other	25	8.5	6	8.0
Total	293	100.0	75	100.0
Signif. of diff.		N.S.		
Road Condition				
Dry	203	70.2	50	67.6
Wet	60	20.8	17	23.0
Snow/ice	26	9.0	7	9.3
Total	289	100.0	74	100.0
Signif. of diff.		N.S.		
Time of Day				
Midnite - 3 AM	12	4.1	29	38.2
3 AM - 6AM	3	1.0	10	13.2
6 AM - 9 AM	38	13.0	2	2.6
9 AM - noon	42	14.4	3	3.9
Noon - 3 PM	53	18.2	6	7.9
3 PM - 6 PM	79	27.1	8	10.5
6 PM - 9 PM	40	13.7	12	15.8
9 PM - Midnite	25	8.6	6	7.9
Total	292	100.0	76	100.0
Signif. of diff.		$P < .001$		
Street Lighting in Night Crashes				
Lighted	53	76.8	29	61.7
Not lighted	16	23.2	18	38.3
Total	69	100.0	47	100.0
Signif. of diff.		$P < .001$		

(Continued)

TABLE 29 (Continued)

	Driver Group			
	Drug free		Alcohol only	
Day of Week	n	%	n	%
Monday	41	14.0	4	5.3
Tuesday	31	10.6	5	6.6
Wednesday	34	11.6	5	6.6
Thursday	54	18.4	9	11.8
Friday	57	19.5	13	17.1
Saturday	56	19.1	16	21.1
Sunday	20	6.8	24	31.6
Total	293	100.0	76	100.0
Signif. of diff.		$P < .001$		
Vehicle Type				
Automobile	232	80.6	56	75.7
Pickup, van etc.	21	7.3	8	10.8
Motorcycle	27	9.4	10	13.5
Other	8	2.8	0	0
Total	288	100.0	74	100.0
Signif. of diff.		N.S.		

Land Use. Zoning maps were used to code land use in the areas immediately adjacent to the accident sites. Table 29 shows that the alcohol-involved accidents were significantly more frequent in residential areas.

Road horizontal alignment. Previous studies have amply documented the overrepresentation of alcohol-involved drivers in curve accidents, and this study finds the same. Table 29 shows that the drinking-driver crashes were especially prominent in left-curves, where wide turns are most likely to take the vehicle off the road. This may be an important clue about impairment effects, but a special chi-square test comparing the drugfree and alcohol-involved drivers on just the curve data showed that the results could have been due to chance. Restudy with a larger sample is warranted.*

Limited data on radii of curvature in curve accidents were available from the pilot phase of the study, when scene examinations were conducted. Because of the small number of cases, an analysis of alcohol effects ignored all other drugs. Results were as follows:

Radius of Curvature	BAC=0	BAC > 0
Less than 700'	2	9
700' or more	4	6
	6	15

The differences between the drivers with and without alcohol were not statistically significant, but they do suggest that alcohol-involved drivers tend to have more difficulty with sharp curves than do sober drivers. The matter deserves reexamination with a larger sample.

*In a large study of highway hazards (Perchonok et al., 1978), left-curve accidents were found more frequent than right-curve accidents by a ratio of 1.6 to 1. Unfortunately, drunk and sober drivers were not compared, but the hypothesis that the general phenomenon is due mainly to impaired drivers may be tested in a larger study.

If alcohol-impaired drivers do have especial difficulty with sharp curves, this again suggests failures in perceiving the sharpness and in reducing speed appropriately. Johnston (1981) suggests that curves overtax the impaired driver's ability to recognize and correctly interpret information necessary to speed control.

Intersections. The tendency of alcohol crashes to occur away from intersections has been well documented (e.g. Perchonok, 1978). Differences between impaired and drugfree drivers in this respect were significant in this study also (Table 29). These results reflect the findings on collision type, viz. that intersecting-path collisions are less frequent than other types among drinking drivers.

Road type. Perchonok's (1978) study found that the drinking-driver accidents were disproportionately on two-lane roads. This study, in contrast, found no significant differences between drugfree and impaired drivers in regard to the road type of their crashes. In Table 29, there is a slightly higher proportion of two-lane crashes among the drinking drivers, but there is also a tendency of overrepresentation on limited access and other divided highways. The differences in results of the two studies may be due to the greater proportion of rural accidents in Perchonok's study.

Road condition. The absence of significant differences between drugfree and impaired drivers on crash road condition again is divergent from Perchonok's (1978) results. He found that the drinking drivers were somewhat overrepresented among crashes on dry road surfaces. The tendencies in this study are slightly in the opposite direction. Since differences were not large in either study, it appears that road condition is minor in differentiating sober from impaired accidents.

Time of day. Another well-documented finding is the strong tendency of alcohol accidents to occur during the early-morning hours. That was found in this study also, with an especially heavy representation of the alcohol-involved crashes occurring between midnight and three A.M. Although a smaller proportion occurred in the 3-6 A.M. period, that time period was also well overrepresented in drinking-driver crashes. While other studies sometimes find drinking drivers also overrepresented in late evening hours (after 9 P.M.), that was not found here.

Lighting in night crashes. One of the questions raised about the overrepresentation of impaired drivers in nighttime crashes is whether that is due primarily to the known tendency for drinking-and-driving to occur at night, or to impaired drivers having especial difficulties with darkness. The latter was indeed indicated by Perchonok's (1978) finding that, among nighttime crashes, drinkers were overrepresented under conditions of no street lighting. While statistically significant, Perchonok's effect was rather slight: about six per cent more drinkers' crashes than sober driver crashes occurred under no lighting. Table 29 shows that this study found the same tendency, but it was more pronounced. This clearer effect may be due in part from the distinction this study was able to make between the drugfree and the alcohol-only. These results increase confidence in the interpretation that alcohol impairment seems to increase the risks of driving in darkness. The alternate explanation would have to be that not only are alcohol-impaired drivers overrepresented on the road at night, they are also overexposed to unlighted streets, even in urban-suburban areas.

Day of week. Alcohol-involved crashes have often been found to occur mostly on weekends. This study also found that, but both drugfree and alcohol-involved crashes were more frequent on Fridays and Saturdays. The two driver groups differed most distinctly on Sundays, when drugfree crashes were least frequent and alcohol crashes were most frequent. (Of the latter, 71 per cent occurred before 6 A.M.)

Vehicle type. As Perchonok (1978) had found, there was a somewhat greater representation of light trucks in the alcohol-involved crashes than in the drugfree. Motorcycles were also represented more in the former. These differences were small, however, and the results on vehicle type were not statistically significant.

Summary and interpretation. The following conditions were over-represented in the crashes of alcohol-involved drivers:

(a) Residential areas

(b) Curve accidents

(c) Occurrence between midnight and 6 A.M.

(d) Saturday and Sunday occurrence

(e) Among nighttime crashes, on streets without lighting.

(f) Away from intersections

The overrepresentation of any of these can be due to (a) overexposure of alcohol-impaired drivers to the condition, (b) especial difficulties that impaired drivers have when exposed to the condition, or (c) both of these effects. Without exposure data, plausibility has to be relied upon to judge the likely significance of either explanation. The following are hypotheses as to which is the best explanation for the overrepresentation of conditions in alcohol crashes:

(a) Residential areas -- Overexposure due to drinking occurring in these areas and/or alcohol-involved drivers are heading home.

(b) Curves -- More hazardous to alcohol-impaired drivers.

(c) Midnight - 6 A.M. time period -- Combination of overexposure and difficulties of impaired drivers with darkness.

(d) Saturday and Sunday -- Drinking drivers are overexposed.

(e) Night crashes on unlighted streets -- Difficulties of impaired drivers with darkness.

(f) Away from intersections -- Gross impairment from alcohol creates difficulties of guidance and control, even in relatively innocuous environment.

What Are the Major "Alcohol Accident Types"?

As indicated in the Introduction, the "targets" for countermeasures may be sharply delineated if it is possible to identify "alcohol accident types" in terms of combinations of collision type and crash circumstances. The search for alcohol accident types used two criteria:

(1) Overrepresentation -- The proportion of alcohol-involved drivers in the accident type should be significantly higher than the proportion of alcohol-involved drivers in other accident types.

(2) Prevalence -- The accident type should account for a significant portion of all accidents of alcohol-impaired drivers.

The first criterion might be used alone if one is interested strictly in identifying any problems, even those small in scope, where the problems are primarily created by drinking drivers. On this basis, wrong-way crashes have been identified as an alcohol problem, despite their minor incidence (Friebele, 1971). The second criterion is important if one wants to focus on problems large in scope, accounting for a major portion of all accidents involving impaired drivers. It cannot be used alone, however, because it might then identify circumstances common to most accidents, with no special relevance to alcohol crashes.

In applying these criteria the procedure was as follows. Collision type, the various circumstance variables, and driver age and sex, were dichotomized to best differentiate groups with high and low proportions of alcohol-involvement (for Criterion 1), while also retaining more than a trivial number of drivers in the high alcohol-involvement group (for Criterion 2). (Alcohol involvement was determined regardless of the presence of other drugs, to maintain sufficient numbers for further breakdowns.) Thereafter a series of two-way, three-way etc. combinations of variables was formed to find those combinations that both had high proportions of alcohol-involved drivers within them and which also accounted for a nontrivial proportion of all alcohol-involved drivers.

Table 30 shows the results when all circumstance variables and collision types were dichotomized. How to interpret Table 30, is explainable by example: Of all the drivers having an accident between midnight and 6 A.M., 75.9 per cent had alcohol in their blood. At all other times, only 15.7 per cent had positive blood alcohol. The first time period accounts for 60 drinking drivers, while other times accounted for 65.

To select the best variables in Table 30, the overrepresentation criterion requires that a "good" variable should have a large difference between the proportions of alcohol-involved drivers in the Best Condition and its Alternate. The prevalence criterion requires that the number of alcohol-involved drivers in the Best Condition be large in comparison with other conditions.

The first two Best Conditions are good candidates for alcohol accident type because they are fairly high on both criteria. The third, accident on curve, is not quite as good because, while fairly high on overrepresentation, it includes only 33 (26.4%) of the total 125 drinking

TABLE 30. - INPUT VARIABLES FOR "ALCOHOL ACCIDENT TYPES"

Best Condition	% with alcohol	vs.	Alternate	% with alcohol	Unknowns on Dimension
1. Midnight - 6 AM	75.9% [60]	vs.	All other times	15.7% [65]	0
2. Single-driver accident	56.0% [75]	vs.	Multi-driver accident	13.1% [45]	5
3. Accident on curve	44.6% [33]	vs.	Accident not on curve	21.1% [85]	18
4. Rain	37.5% [24]	vs.	Other weather	23.0% [97]	4
5. Fri.-Sat.-Sun.	34.0% [82]	vs.	Other days	17.0% [43]	0
6. Pickup, van etc.	33.3% [14]	vs.	Other vehicles	24.2% [127]	4
7. Male driver	30.7% [95]	vs.	Female driver	16.2% [30]	0
8. Divided highway	30.4% [14]	vs.	Other roads	22.2% [108]	3
9. Nonintersection	30.4% [65]	vs.	Intersection related	20.3% [54]	14
10. Driver age < 50	29.3% [121]	vs.	Driver age 50+	4.9% [4]	0
11. Residential area nearby	28.6% [82]	vs.	No residential area nearby	20.0% [29]	62
12. Urban area	28.4% [71]	vs.	Suburban-rural	21.9% [53]	1

Note: Numbers in brackets indicate number of alcohol-involved drivers in group.

drivers. A contrasting Best Condition is driver age under fifty; it included 121 of the drinking drivers, but only 29.3 per cent of drivers under fifty were alcohol-involved.

Clearly, the numbers involved in the Best Conditions and Alternates depend on how each variable is dichotomized, which should be done to yield the joint optimum on both criteria. This was done partially by judgment, although a computer analysis might be used to find the exact best dividing point.*

Finding the best combinations of conditions was accomplished by cross-tabulating variables, beginning with the most promising ones. This was done selectively rather than by attempting the enormous task of examining all possible cross-tabulations. (Again, a computer program could be used to find the most elegant solution.)

Combinations were attempted using the variables dichotomized from Time of Day, Single vs Multiple Vehicle, Horizontal Alignment, Day of Week, Sex, Age and Intersections (1,2,3,5,7,9 and 10 in Table 30), which were chosen by judgments of their relative strength on the two criteria. The first three produced alcohol accident types meeting the criteria well, and these are shown in Table 31. The five types shown accounted for 75 per cent of all the alcohol-involved drivers with known circumstances, and in each of these, the proportions of alcohol-involved drivers exceeded the overall proportion of 25.3 per cent.

The first alcohol accident type comprised drivers in a single-driver crash occurring between midnight and 6 A.M. on a curve. Of all drivers having an accident in those circumstances, a substantial 95 per cent of them were alcohol-involved.

*A program known as the Automatic Interaction Detector (Sonquist et al., 1973) can be used, although it was not available for the analysis here. Its use is not recommended for samples with fewer than 1000 cases.

TABLE 31. - ALCOHOL ACCIDENT TYPES

	(1) All drivers	(2) Ethanol involved	(2) ÷ (1) % Ethanol involved
Alcohol Accident Types			
Single driver; midnite - 6 AM; on curve	21	20	95.2%
Single-driver; midnite - 6 AM; on straight section	29	24	82.8%
Multiple drivers; midnite - 6 AM	27	14	51.9%
Single driver; other times; on curve	22	9	40.9%
Single driver; other times; on straight section	64	21	32.8%
Not Alcohol Accident Types			
Multiple drivers; other times	314	30	9.6%
Unknown	17	7	[41.2%]
	494	125	

Summary. An analysis was made to identify "alcohol accident types," defined as those combinations of collision type and crash circumstances in which alcohol-involved drivers are most highly represented. In searching for these conditions, an effort was made also to try to account for the highest proportion of all drinking drivers with the fewest number of "alcohol accident types."

Altogether, twelve different circumstances and collision type variables were examined. Each continuous variable was dichotomized to best differentiate groups of high and low proportions of drinking drivers. The next step sought the combinations of circumstances which yielded the highest proportions of alcohol-involved drivers while also producing groups nontrivial in size. Identified were five circumstances which included three-quarters of the alcohol-involved drivers with known crash circumstances. The most outstanding "alcohol accident type" was that of a single driver crash occurring between midnight and 6 A.M. on a curve; 95 per cent of these involved a drinking driver.

Of interest was the fact that driver age and sex were not important to the alcohol accident types; they could be used to create types with higher proportions of drinking drivers, but those types would include only small numbers of drivers.

Two important caveats are necessary in regard to these results:

(1) The patterns may be peculiar to Rochester area crashes, or only to drivers treated at Rochester General Hospital. Thus, it would be unwise to regard the alcohol accident types identified here as universal.

(2) The problem of small numbers could produce idiosyncratic patterns, especially among any types comprising few drivers.

Under What Circumstances Did the Single-Driver Crashes of Sober and Impaired Drivers Occur?

While the collision types overrepresented among alcohol-involved drivers were assumed in Chapter 6 to result from alcohol impairment, a tenable alternative explanation is that those collision types were due more to the special circumstances in which the accidents occurred. For example, single-driver crashes could be prevalent among alcohol-involved drivers simply because their accidents commonly occur in early-morning hours, when fewer cars are on the road. Consequently, the effects of alcohol impairment may be better inferred by comparing the collisions of sober and impaired drivers within the same circumstances. Doing this thoroughly is an extensive undertaking, however, so here only selective and simplified analyses were made. Because of the problem of limited numbers, (a) concentration is on single-driver crashes, and (b) all drivers with any alcohol rather than alcohol-only are examined.

Figure 11 shows that the proportion of single driver crashes increased when traffic density was lighter, as might be expected. A relevant point for alcohol-impairment is that, for any combination of day or night and traffic density, the alcohol-involved drivers had far greater proportions of single-driver crashes than the drugfree. Thus, the overrepresentation of single-driver crashes among drinking drivers cannot be explained as due simply to the occurrence of crashes in light traffic at night.

(An important reminder is that we have no exposure data to show the relative probabilities of any type of crash for sober and impaired drivers. Therefore, any statements about the relative probability of single-driver crashes are made by way of inference.)

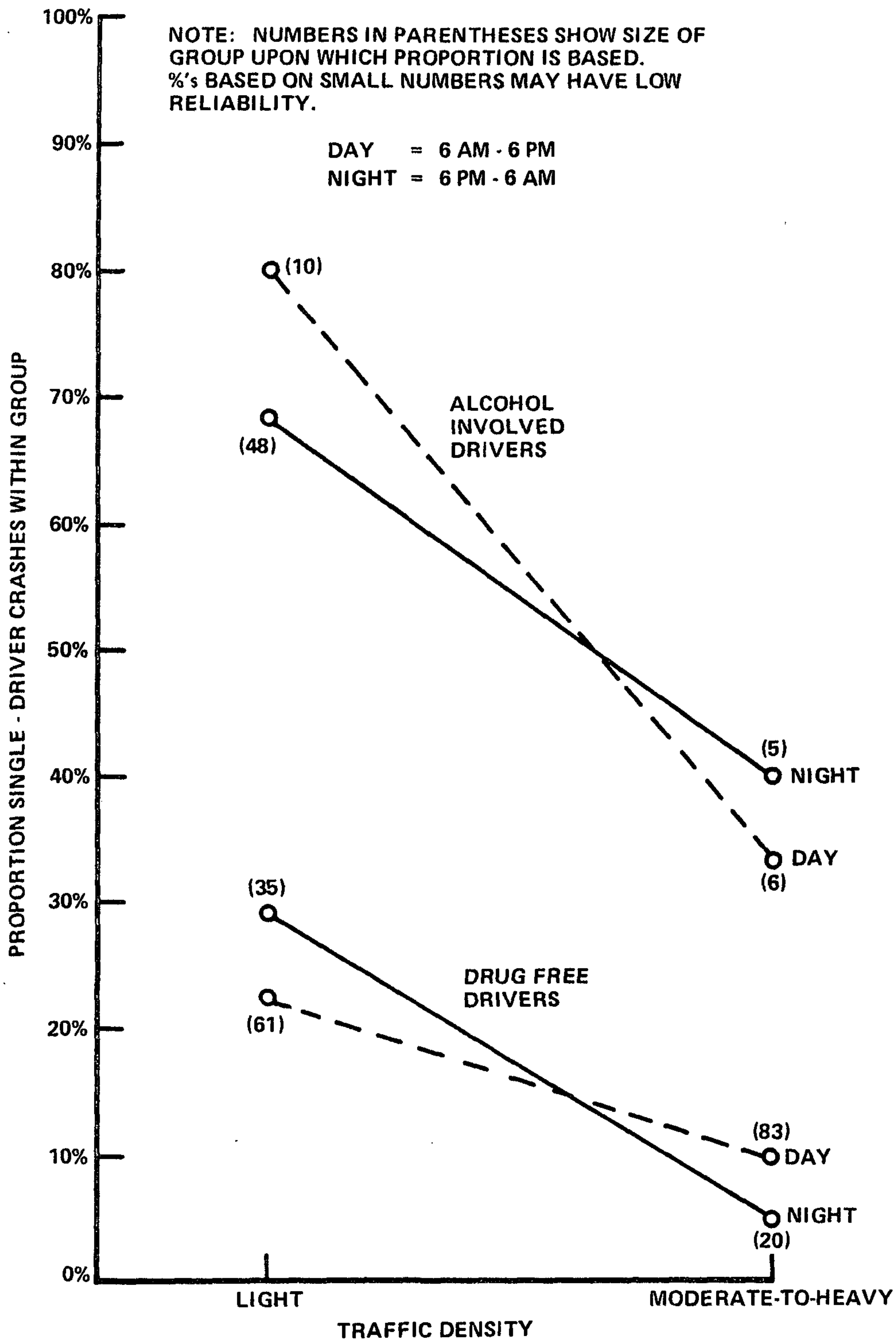

Figure 11 SINGLE-DRIVER CRASHES IN RELATION TO TRAFFIC DENSITY, TIME OF DAY AND ALCOHOL INVOLVEMENT

Earlier it was observed that alcohol-involved drivers seem to have special problems in darkness. The results in Figure 12 suggest that darkness induces single-driver crashes with sober drivers as well as the alcohol-impaired. The effect seems much more pronounced among the latter, however.

Earlier, Table 18 showed that the age groups most culpable in their crashes were the youngest and oldest drivers. Figure 13 clarifies that relationship further, by which it can be seen that among the drugfree, single-driver crashes were most pronounced for the teenaged and elderly drivers, especially the latter. At each age group of the alcohol-involved, single-driver collisions are much more prevalent. A point that may be inferred from Figure 13 is that, with respect to single-driver crashes at least, alcohol seems to have an effect similar to old age in impairing drivers.

Finally, Figure 14 shows that road surfaces made slick by snow or ice were associated with increased proportions of single-driver crashes. The effect is most pronounced among sober drivers; the alcohol-involved seem to have such a strong propensity to single-driver crashes even on dry roads, that slick surfaces increase the proportion only moderately. Another point to be inferred here is that alcohol resembles slippery roads in its effects of apparent control loss.

Summary. Single-driver crashes were shown to increase proportionately in light traffic, in darkness, with driver old age (and in small degree, with youth), and on snowy and icy road surfaces. All these effects were apparent with drugfree drivers, but in every one of the conditions, alcohol-involved drivers had substantially higher proportions of single-driver crashes than did the drugfree drivers. Two main points are inferred from these results:

(1) The evidence points to alcohol impairment *per se* as a cause of single-driver crashes, apart from the effects of circumstances in which alcohol crashes take place;

(2) In its relation to single-driver crashes, alcohol impairment resembles the effects of darkness, old age, and slick road surfaces.

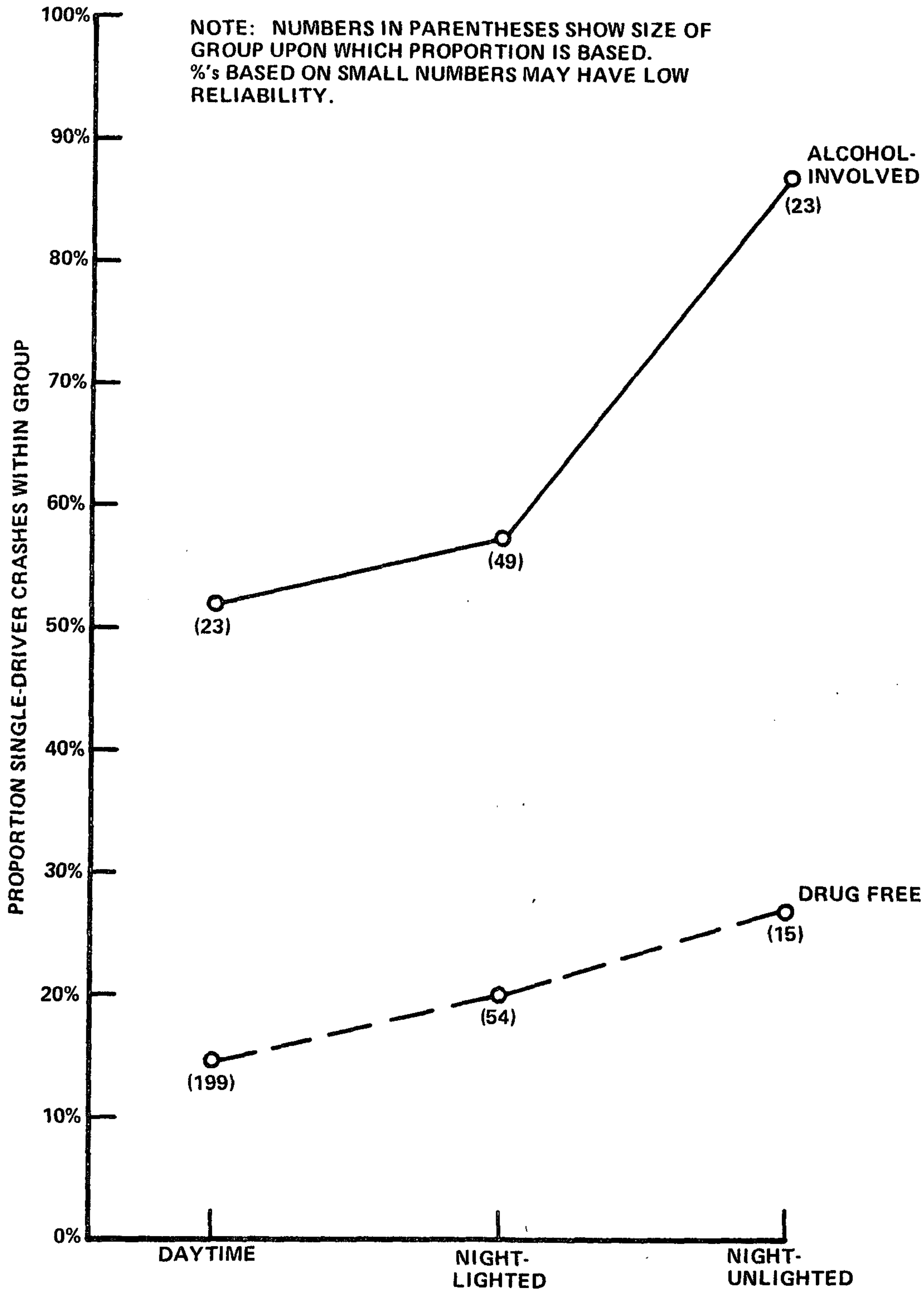

Figure 12 **SINGLE-DRIVER CRASHES IN RELATION TO STREET LIGHTING AND ALCOHOL INVOLVEMENT**

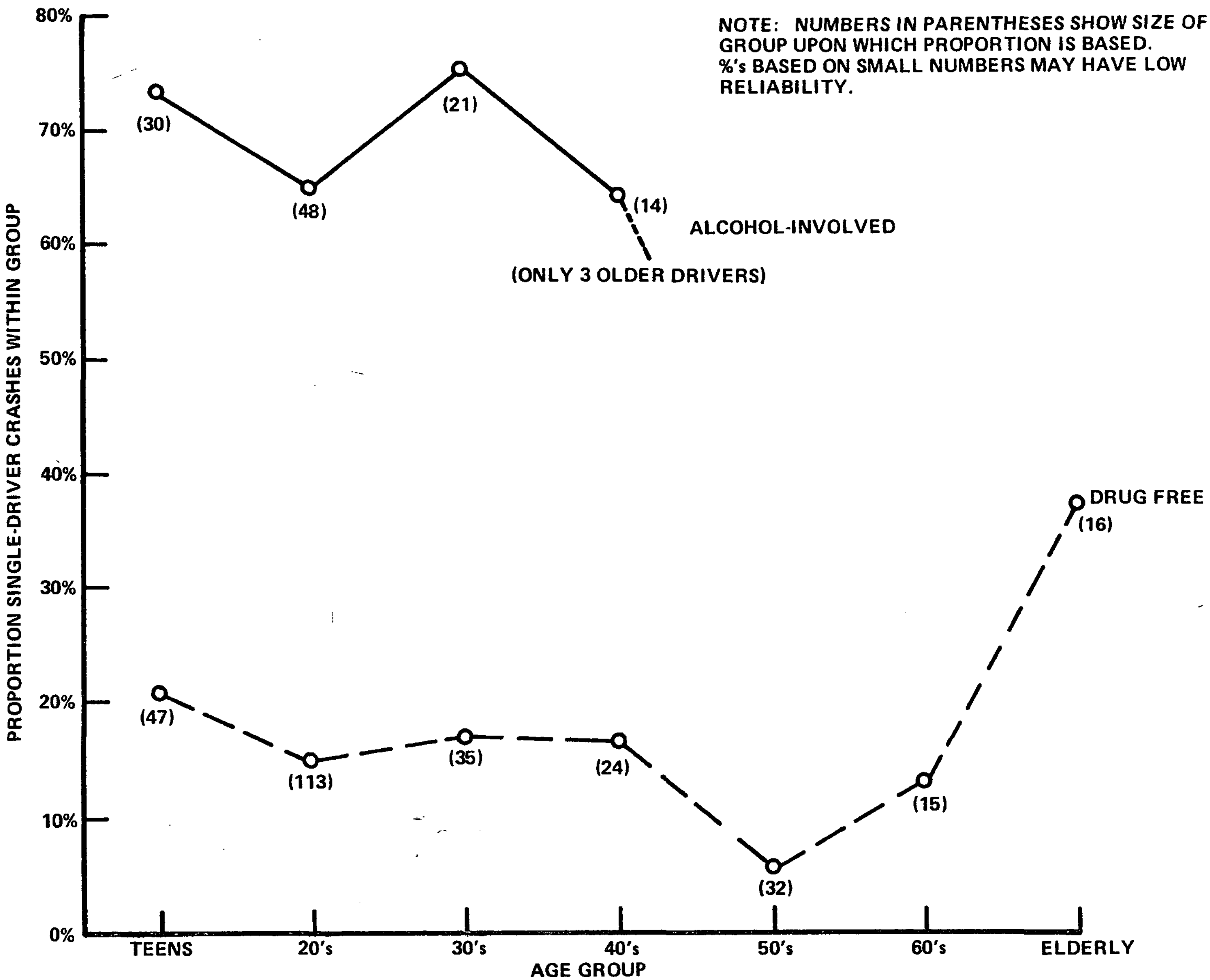

Figure 13 SINGLE-DRIVER CRASHES IN RELATION TO AGE AND ALCOHOL INVOLVEMENT

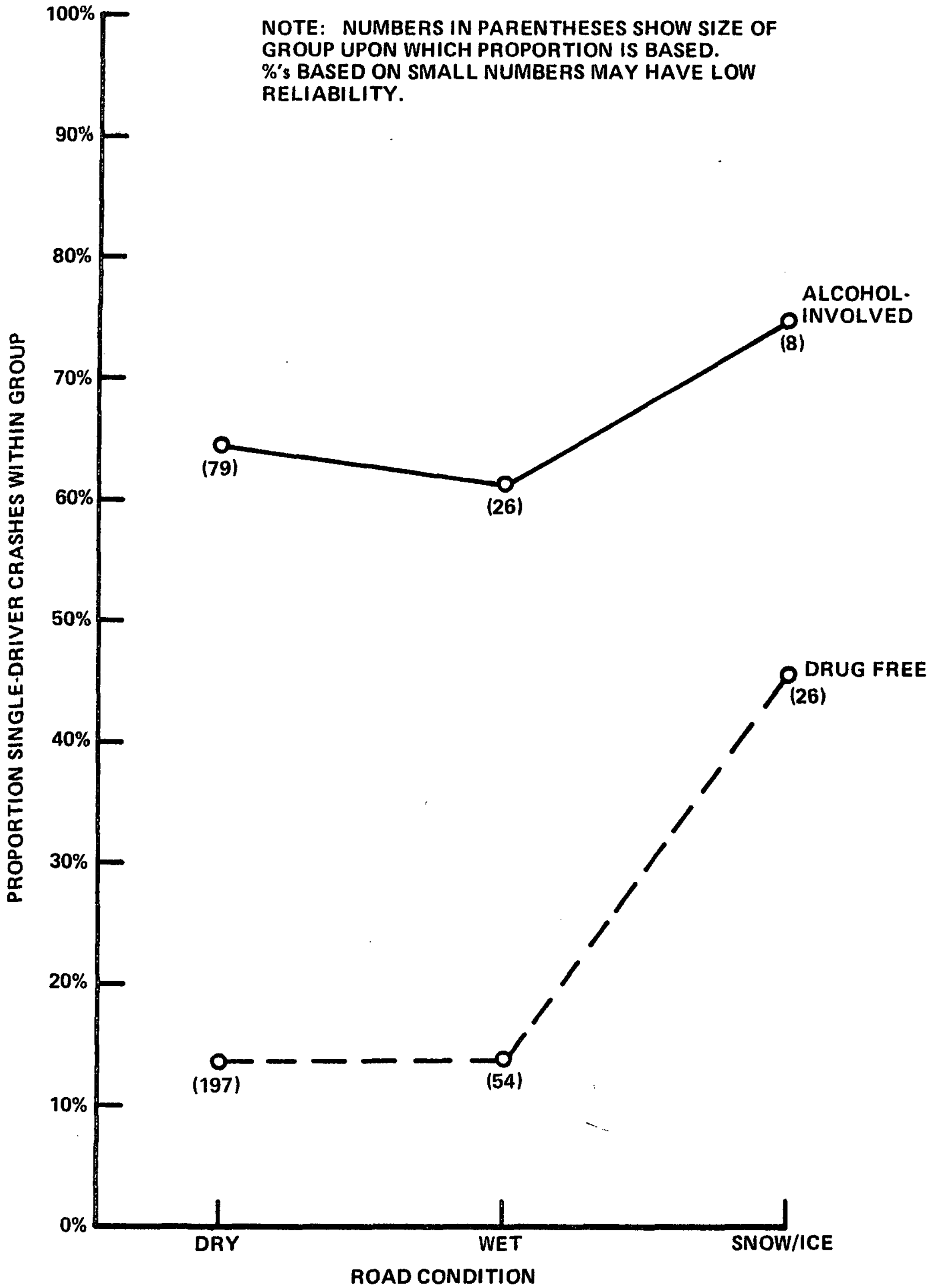

Figure 14 SINGLE-DRIVER CRASHES IN RELATION TO ROAD CONDITION AND ALCOHOL

How Accurate Were the Police and the Hospital Nurses in Identifying Impaired Drivers?

Answers to this question can be valuable in three different ways:

(a) Since some of the analyses used the ETOHOUT drivers for a partial replication of the analysis of alcohol-involved "in" drivers, it is important to know how sure we can be that the "out" drivers judged to have been alcohol-impaired were so in fact.

(b) The results can reveal how useful police and medical staff judgments can be as proxies to BAC tests in research investigations.

(c) The results can suggest how effective police are in detecting and reporting alcohol-involved drivers in accidents, a matter related to the issue of enforcement as a means to deter impaired driving.

Police indications. The analysis of police accuracy was made on the 472 "in" drivers with a blood sample and a police report. The results in Table 32 reveal the following:

(a) When the police indicated a driver to be alcohol-involved, they were correct 96 per cent of the time (49 out of 51 drivers);

(b) Of all the drivers with alcohol in their blood, the police indicated alcohol involvement on only 42 per cent (49 out of 117 drivers).

In other words, when the police reported a driver's alcohol-involvement, they were nearly always correct. However, in not reporting alcohol involvement, they missed many drinking drivers. Part of Table 32 shows that few of the low-BAC drivers were identified as alcohol-involved, and even at BAC's of .20% and above, no mention of alcohol was made in 42 per cent of the police reports. One

TABLE 32. - ACCURACY OF POLICE ACCIDENT REPORTS IN NOTING DRIVER ALCOHOL INVOLVEMENT

A. Overall Results

BAC	Police Indication of Alcohol: None	Involvement Noted	DWI Citation	Total
0	99.4%	0.3%	0.3%	100.0%
	(353)	(1)	(1)	(355)
.01-.09%	81.5%	7.4%	11.1%	100.0%
	(22)	(2)	(3)	(27)
.10-.19%	55.9%	28.8%	15.3%	100.0%
	(33)	(17)	(9)	(59)
.20%+	41.9%	38.7%	19.4%	100.0%
	(13)	(12)	(6)	(31)

B. Hits and Misses Summarized

		Police Indication: No alcohol	Alcohol
Blood Test	No alcohol	353 correct	2 false positives
	Alcohol	68 false negatives	49 correct

C. Drinking Drivers Correctly Identified

.01-.09%	BAC	-	18.5%	correctly identified
.10-.19%	BAC	-	44.1%	" "
.20%+	BAC	-	58.1%	" "
Overall		-	41.9%	" "

might think that impairment would be fairly obvious at that level, but that may not always be true.

It may be recalled from the Introduction that Perchonok (1978) used police "Had Been Drinking" notations and Driving While Intoxicated citations as proxy indicators of low and high positive BAC's, and on this basis he inferred differential effects of alcohol levels. While Perchonok's assumption was not unreasonable, the data here do not support it. From Table 32 the following may be constructed:

Police Alcohol Indic.	BAC 0	.01-.09%	.10-.19%	.20%+	Totals	
Involve. noted	3.1%	6.3%	53.1%	37.5%	100.0%	(32)
DWI	5.3%	15.7%	47.4%	31.6%	100.0%	(19)

Thus, a DWI citation appears no more likely to indicate an intoxication-level BAC than is the notation of alcohol-involvement. In fact, there is a slight tendency for the opposite effect.

What leads a police officer to note the alcohol-involvement of some drivers with positive BAC's, but not others? An analysis here revealed that the police report included an alcohol citation or notation for 49.5 per cent (46/93) of the BAC-positive drivers whom our coders judged culpable or possibly so. Of those judged not culpable, only ten per cent (2/20) had an alcohol citation or notation. Clearly then, being <u>responsible</u> for an accident greatly increased an impaired driver's chances of the police putting the alcohol involvement on record.

<u>Hospital indications</u>. Because the Emergency Department nurses had seen all 494 drivers on whom a blood analysis was performed, all these drivers were used to assess nurse accuracy in alcohol identification. As noted earlier in this report, however, the staff made a serious effort to detect drinking

drivers only when this was stressed later in the project; consequently, the results of the analysis here may underestimate their potential to identify alcohol involvement.

The results in Table 33 show that the performance of the nurses was remarkably similar to the police. The nurses correctly identified nearly as many of the impaired drivers as did the police. They did miss somewhat higher proportions in each BAC group than did the police.

The clues used by the nurses are shown in Part A of Table 33. The relative accuracy of each of these is as follows:

Nurses' Alcohol Indic.	BAC 0	.01-09%	.10-.19%	.20%+	Totals	
Drunk behavior	0%	14.3%	42.9%	42.9%	100.0%	(7)
On breath	3.6%	7.1%	50.0%	39.3%	100.0%	(28)
Driver admits	15.4%	0%	53.3%	33.3%	100.0%	(15)

It appears that drunk behavior was the most accurate clue to alcohol involvement, although that judgment was made in only seven cases. Surprisingly, the admission of drinking by the driver appears to be the least accurate indication of alcohol! Perhaps in the two cases where that clue seems wrong, the blood was drawn so long after ingestion that it no longer contained the ethanol.

Since the data have shown that the police correctly identified about 42 per cent of the alcohol-involved drivers, and the nurses identified 38 per cent, it is of some interest to know whether combining their judgments would improve the identification rate. An analysis showed that by accepting a positive judgment from <u>either</u> source as the indicator, 58 per cent of the alcohol-involved drivers would have been correctly identified. Clearly, pooling judgments improves identification.

TABLE 33. - ACCURACY OF EMERGENCY DEPARTMENT NURSE REPORTS OF DRIVER ALCOHOL INVOLVEMENT

A. Overall Results

BAC	None	On breath	Driver Behavior	Driver admits	Total
	Indication of Alcohol				
0	99.2%	0.3%	0%	0.5%	100.0%
	(366)	(1)	(0)	(2)	(369)
.01-.09%	89.3%	7.1%	3.6%	0%	100.0%
	(25)	(2)	(1)	(0)	(28)
.10-.19%	60.3%	22.2%	4.8%	12.7%	100.0%
	(38)	(14)	(3)	(8)	(63)
.20%+	44.1%	32.4%	8.8%	14.7%	100.0%
	(15)	(11)	(3)	(5)	(34)

B. Hits and Misses Summarized

		Emergency Department Indication	
		No Alcohol	Alcohol
Blood Test	No alcohol	366 correct	3 false positives
	Alcohol	78 false negatives	47 correct

C. Drinking Drivers Correctly Identified

.01-.09% BAC - 10.7% correctly identified
.10-.19% BAC - 39.7% " "
.20%+ BAC - 55.9% " "

There was a further significant contrast in the pooled data. It was found that 67.0 per cent (65 out of 97) of the legally intoxicated (BAC $\geq$ .10%) drivers had been correctly identified as alcohol-involved by either the police or nurses, yet as Table 32 shows, only 16.7 per cent of the intoxicated drivers were given a DWI citation.

Summary. The examination of the police and Emergency Department nurse reports of alcohol involvement revealed quite similar performances by both groups. When they indicated a driver was alcohol-involved, he nearly always was. On the other hand, both groups failed to note alcohol in most drivers who had positive BAC's.

The higher the BAC, the more likely were both police and nurses to correctly identify him as a drinking driver; apparently the behavioral clues become more pronounced as blood alcohol increases. Even so, the police and nurses respectively missed many drivers at very high BAC's of .20% and above.

While the nurses did nearly as well as the police in identifying alcohol involvement, the data probably underestimate what the nurses would have done had the behavioral identification of drinking drivers been stressed from the beginning of the project.

The differences between police notation of alcohol involvement versus their giving a DWI citation did not distinguish drivers by BAC level. While this finding may pertain only to the Rochester area, it indicates that police reports cannot be simply assumed to validly distinguish BAC levels.

8. CIRCUMSTANCES OF CRASHES INVOLVING MARIJUANA AND TRANQUILIZERS

Although the frequencies of any drug besides alcohol were fairly small, it may be helpful to future research to record here some observations about the crashes of drivers involved with the main additional substances, marijuana and tranquilizers.

Marijuana Crash Circumstances

While there was no collision type that differentiated the cannabis crashes from the drugfree ones, there were some ways by which the crash circumstances of the two groups differed. These are listed below.

	Proportions of Crashes	
	Of THC-only Drivers	Of Drugfree Drivers
Male driver	88.2%	58.2%
Dry road surfaces	88.2%	70.2%
Noon - 9 PM occurrence	76.5%	58.9%
Age 21 - 30	70.6%	39.9%
Motorcycle	35.3%	9.4%
Rain/Snow	5.9%	19.4%
Winter	11.8%	21.2%
Denominator for %'s	17	293

The young male characteristics of the marijuana drivers were already mentioned in Chapter 6. In the data presented here, it is seen that marijuana crashes are distinguished by their predominant occurrence in the afternoon and early evening. This distinguishes them not only from the drugfree crashes, but from the early morning pattern of the alcohol-involved crashes as well. Very few of the marijuana crashes occurred in rain or snow, and winter crashes were half as frequent as among the drugfree. Standing out from all other driver groups was a prevalence of motorcycles.

While the small numbers preclude the determination of a "marijuana accident type," the data presented suggest a fairly clear picture. An image is conveyed of young male drivers, often on motorcycles, on an outing in daylight during good weather.

Tranquilizer Crash Circumstances

With no evidence that the tranquilizers found in some drivers had contributed to their crashes, the idea of a "tranquilizer accident type" may have little meaning. Nevertheless, there are a few differences between the drugfree and tranquilizer drivers in their crash circumstances. A description of these circumstances may provide more of a social commentary on tranquilizer use than a description of a highway safety problem, but the description may be heuristic should tranquilizers yet prove to be a problem.

The salient aspects of the crashes of tranquilizer-only drivers were as follows:

	Proportions of Crashes	
	Of Tranquilizer-Only Drivers	Of Drugfree Drivers
Age 31-64	73.7%	34.8%
Female driver	63.2%	41.6%
Suburban location	63.2%	48.6%
Summer Accident	42.1%	28.7%
9 AM - Noon, 6 PM - 9 PM	57.9%	28.1%
Denominator for %'s	19	293

Whereas the tranquilizer group as a whole was found to have a sex composition similar to the drugfree group (Chaper 6), the tranquilizer-only drivers had a greater representation of female drivers. The tranquilizer-only accidents were also more suburban, occurring in the summer, and occurring in the early morning or evening hours.

It is important to realize that the above circumstances are only the most salient ones, and other patterns exist also. Nearly forty per cent of the tranquilizer-only drivers were men, and their use of tranquilizers might involve a pattern differing from the women. Were the analysis expanded to tranquilizers plus other substances, even different patterns might be found. For example, the tranquilizer chlordiazepoxide (Librium)® was found in five drivers,all males ranging in age from 35 to 62. In four of the drivers at least one other substance was present also. With such small numbers, however, no meaning should be attributed to such patterns.

Summary and discussion. Just as there were certain dominant circumstances pertaining to the crashes of alcohol-involved drivers, so there were distinctive patterns suggested in the marijuana-only and tranquilizer-only crashes. The former include mainly males in their twenties, and their crashes characteristically occurred in daylight or early evening hours in clear weather. In contrast, the tranquilizer-involved crashes generally included women and drivers in the 31-64 age group, and their accidents were typically in suburban areas, in the daytime, and during summer.

While a larger sample might make possible the discernment of a "cannabis accident type" and a "tranquilizer accident type", there would be little meaning to such types unless the drugs are shown to increase crash risks.

It is certainly necessary to realize that the circumstances associated with marijuana, tranquilizers, and alcohol crashes in this study may be highly limited as to place and time. That is, outside of the Rochester, New York area, and/or in other decades, the same patterns may not be found. Alcohol and drug use are social phenomena and as such they are subject to myriad influences that can cause their popularity to wax and wane.

A broader implication here is that despite our attempts to use statistical controls to isolate "pure" effects of substances apart from confounding variables, those effects cannot be wholly separated from the pattern of circumstances associated with substance-involvement in crashes. Complete separation of drug impairment effects from circumstance effects may be as difficult of realization as separating drug effects from the characteristics of people who use those drugs.

9. DISCUSSION

Throughout this report, various limitations of the study have been discussed, in order to provide perspective in judging the significance of the findings. These limitations will be briefly reviewed below, and then the major substantive issues will be discussed.

Limitations of the Study

(1) Restricted sample. This study sample was limited to (a) injured drivers, (b) at one hospital, (c) within one American metropolitan area. The results do not necessarily apply to fatal or property-damage-only accidents, nor to other cities or rural areas.

(2) Sample bias. As to incidence rates, the sample probably underestimates the proportion of alcohol-involved drivers, though it is unclear whether there may be similar underestimates of other drugs. Certainly, however, the incidence rates of this study can be considered only suggestive of rates that may be found in similar crashes elsewhere. As to crash characteristics and relationships, a relevant question is whether drivers who consent to a blood sample may be more compliant or less guarded than drivers who refuse, and whether there may be associated differences in their accidents. While it seems reasonable to expect some differences, it was not obvious from the comparisons made that drinking drivers included in the study differed a great deal from the excluded drivers whom the police reported as alcohol-involved.

(3) Small sample. Repeatedly mentioned in presenting the results was the problem of small numbers in the subsamples. The statistical danger of this is clear, for the likelihood of some findings being due to chance is increased; this will necessarily be true even for some statistically significant findings.

The implication is that all apparently new findings i.e., those that are not replications of previous ones, should be regarded as tentative until subjected to further study.

(4) Qualifications on impairment effects. The test of whether a substance significantly impaired drivers was the comparison of culpability rates between substance-involved and drugfree drivers. Because these analyses were so fundamental to the project objectives, considerable effort was made to control for related and possibly confounding variables. The results were encouraging in generally supporting the culpability findings in the various analyses, but no analysis controlled for all the possibly confounding variables (e.g. age, sex, interview status) simultaneously. It is possible that as each was controlled, another confounding variable was influencing the results. Furthermore, it was not possible to control for (a) special characteristics (e.g. driving skill) of the substance users, nor (b) the conditions under which the substance users drive. Perhaps the most encouraging evidence that impairment effects were being detected lies in the correlations between culpability rates and BAC levels and THC levels. These, of course, need further examination in other studies.

(5) Qualifications on determining forms of alcohol impairment. Impairment effects were inferred from the crash characteristics of the alcohol-impaired drivers, but necessarily there is no assurance that those inferences are valid. Establishing their validity must reside in their convergence with results from experimental studies and other accident research. The convergences in turn may suggest countermeasures whose effectiveness may be empirically evaluated.

Culpability Analysis

Earlier in the report it was suggested that culpability rates and relative crash risks ought to be correlated. Farris et al. (1976) provided not only relative crash risks in relation to BAC, but data from which culpability rates may be determined. The anticipated relation was supported:

BAC Group	Culp. Rate	Relative Risk Factor
000 - .029 %	46.8%	1.00
.030 - .059 %	58.6%	1.52
.060 - .099 %	70.9%	1.86 (For BAC group .060 - .089)
.100 - .149 %	84.8%	8.11 (For BAC group .090 - .149)
$\geq$ .150 %	93.5%	22.00

Although the expected positive relationship exists, culpability rates appear to underrate the degree to which crash risk is magnified by alcohol. It does appear, however, that when exposure data are unavailable for computing crash risks, culpability rates may be used to rank-order driver groups by their apparent accident propensities.

Crash-Relevant Effects of Alcohol Impairment

Prior to this study, experimental research revealed many ways by which alcohol can impair human task performance. That at least some of these impairments seem to increase crash risk was indicated by field studies showing systematic relations between driver Blood Alcohol Concentrations and relative crash risk. Well established also was the overrepresentation of alcohol-involved drivers in single-vehicle crashes. There was still uncertainty, however, as to which of the many forms of alcohol impairment are the significant contributors to accident causation.

This study has provided additional clues as to the crash-inducing effects of alcohol. It is now more apparent that alcohol-involved drivers are overrepresented not only in single-driver crashes, but in rear-end-strike and opposite-direction-strike (e.g., head on) crashes as well. They seem least likely to be involved as drivers of the "victim" vehicle in such crashes. These collision types suggest that reduced driver alertness and attention, and perhaps decrements in tracking ability and motor coordination, were contributors to the crashes. A further clue, though less clearly established, was the tendency for the drinking drivers to be involved in overtaking collisions in which the forward vehicle was moving at a slower speed than the alcohol-driver's striking vehicle. Here, speed-distance misjudgments are suggested.

Examining the circumstances of single-vehicle crashes of sober drivers suggested that these crashes are more likely in light traffic, in darkness, on slick road surfaces, and when the driver is elderly. Under each condition, the alcohol-involved drivers had proportionately more single-driver crashes. One implication of these results is that the distinct overrepresentation of drinking drivers in single-driver crashes cannot be attributed solely to their tendency to be driving in darkness in light traffic, although that tendency probably is relevant. Another implication is that alcohol may have effects on drivers similar to old age and slick roads, i.e. by reducing alertness and impairing vision (presumed old age effects) and by reducing physical control over the vehicle (presumed slick road effect).

The analyses were also revealing for two interrelated issues. The first issue is whether alcohol increases crash risks mainly by sedation and "underarousal," or by reducing normal inhibitions against speeding and reckless driving. The second issue is, if alcohol induces recklessness, whether that happens mainly at low BAC's or high ones.

Since alcohol-involved drivers are highly overrepresented in single-driver crashes, the forms those crashes take provide clues as to alcohol impairments. The preponderance of passive road departures in comparison with active ("out-of-control") ones suggests that reduced alertness or arousal is a problem more common than recklessness and speeding among drinking drivers.* The single-driver-forward impact collision, though a minor alcohol type, especially indicates gross inattention. The resemblance of all single-driver crashes to the effects of darkness and old age on sober drivers, while suggestive only through analogy, is nevertheless consistent with other indications of perceptual impairment and reduced alertness as the main alcohol impairments effecting crashes.

While these dominant problems were indicated, the active road departure was a minor alcohol collision type, and it may be inferred that some of these crashes involved recklessness and speeding. A caveat necessary is that some of the apparently "passive" road departure crashes also may have involved recklessness and speeding, but the data were insufficient to reveal that. (Drivers would probably be unwilling to admit recklessness to an interviewer.)

The graph presented as Figure 10 (Chapter 6) was provocative in indicating that the relative frequencies of alcohol-collision types vary in a complex way with BAC, and perhaps that is why some controversy has existed as to whether alcohol-induced recklessness is a low or high-BAC phenomenon, if it exists at all. While the results in Figure 10 certainly require replication before they may be considered reliable, they do suggest that "disinhibition" leading to recklessness and vehicle loss of control is an intermediate-BAC (.10-.19%) phenomenon. While the passive road departures prevalent among low-BAC (.05-.09%) drivers suggest reduced attention, very high BACs (.20% and up) were associated with crashes that suggest <u>gross</u> inattention and underarousal.

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*The problems may differ, however, among drinking drivers in fatal accidents.

The overrepresentation of alcohol-involved crashes on curves now seems to be a well-established finding. This study has added to that by providing data, albeit limited, suggesting that sharp curves and left curves especially are troublesome to alcohol-impaired drivers. Whether or not these are genuine tendencies needs to be established in a study with a larger sample.

The scope of the alcohol problem. While this one study in one city is no basis for inferring the scope of the current highway alcohol problem nationally, it is striking that the proportion of alcohol-involved drivers was close to the average found in earlier studies of alcohol among injured drivers. Because of the driver refusal problem, however, the obtained incidence rate of 25.3 per cent alcohol-involved drivers is in all likelihood an underestimate. *If* this situation is repeated elsewhere in the country, it would seem that alcohol is at least as serious a highway safety problem as ever.

Are There Crash-Relevant Effects of Cannabis Impairment?

From the results of the culpability analysis, tetrahydrocannabinol *seems* able to impair drivers sufficiently to increase crash risk. This is an inference, of course, for (a) culpability analysis is not equivalent to crash risk analysis, (b) our THC analysis was based on a small sample of drivers, and (c) the analysis was not able to control for driver attributes and conditions of driving exposure.

If marijuana does indeed raise crash risks, why was it that the collision types of the marijuana-involved drivers differed so little from those of the drugfree drivers? One possible answer is that THC increases the risk of *all* types of collisions to the same degree, hence their proportions remain about the same as for the drugfree drivers. While this is hypothetically a possibility, it seems unlikely that a drug would impair all crash-relevant skills so uniformly. A more likely explanation is that THC does increase the chances of some collision types, but those types were obscured in the small marijuana sample, which included drivers with very low THC levels . To detect characteristic collision patterns of marijuana impairment, a sample of at least fifty drivers with THC levels exceeding .002 mcg/ml may be needed.*

Marijuana, like alcohol, was found predominantly in crashes of younger male drivers. Unlike the alcohol crashes, however, those involving marijuana-only appeared mainly in the daytime, and they were found somewhat more in good weather. If these conditions reflect the general conditions in which THC-only drivers are on the road, the favorable circumstances may reduce the crash risk relative to alcohol. Perhaps if marijuana-influenced drivers were on the road more at night, their impairment would be more pronounced.

As to the scope of marijuana as a highway safety problem, it seems small relative to the alcohol problem. Although nearly ten per cent of the crash drivers had THC in their systems, the levels of the drug were so low in about half of them that the effects appeared insignificant. A somewhat higher proportion of marijuana-involved drivers might be expected in fatal accidents, and the Ontario rate of twelve per cent (Warren et al., 1980) suggests what that proportion might be in this country.

Are There Crash-Relevant Effects of Tranquilizers and Other Drugs?

This study indicated that tranquilizers were the third most prevalent substance group among the crash drivers, but there was no evidence that the tranquilizers contributed to accidents; the culpability rate of these drivers was no higher than that of the drugfree, and their collision types appeared no different. Yet this one study does not justify a conclusion of "no problem," for the Ontario driver fatality study (Warren et al., 1980) indicates otherwise. To be sure, that study had a small sample of tranquilizer-involved drivers, and we do not know the reliability of the culpability assessments, hence the possibility of spurious results cannot be wholly ruled out. On the other hand,

*The drivers should have THC only in their blood; an equal sample of drivers with THC plus ethanol also should be analyzed. It is also very desirable to have a sufficient number of drivers at higher THC levels (say, beyond .010 mcg/ml) for analysis.

evidence of diazepam levels somewhat higher than in the drivers of this study suggests that dosages levels may partially explain the different results of the two studies. In addition, a sample of fatally injured drivers may select those with more critical responses to tranquilizers.

With regard to tranquilizers as with other substances, the effects of driver characteristics and driving conditions cannot be wholly ruled out. The tranquilizer-only drivers may be especially cautious types, and their driving conditions may be less hazardous (the tranquilizer-only crash circumstances tended to be suburban and in morning and early evening hours). Nevertheless, this study provides no basis for designating tranquilizers as a highway safety problem.

Concern is sometimes expressed that tranquilizers in combination with alcohol may have an additive or interacting impairment effect. It may be noted that only a minority of the tranquilizer-involved drivers had also ingested alcohol, and the culpability rate of the drivers was inconclusive as to whether there was any effect beyond that due to the alcohol.

Considering the results of this study and the Ontario one, the question of whether tranquilizers constitute a highway safety problem remains open, and further study is needed.

Other drugs. Incidence rates for drugs and drug groups other than alcohol, THC, and tranquilizers were insufficient to analyze them separately, so they had to be analyzed together in an "other-positive" group of drivers. Although this group had a culpability rate about ten per cent higher than that of the drugfree drivers, the differences were not statistically significant. Therefore, the hypothesis that other drugs produced no crash-relevant impairments remains tenable. It is possible, of course, that the heterogeneous mixture of drugs in this group obscured the effects of individual substances.

On balance, the results hint at the possibility that some low-incidence drugs decrease highway safety, but a larger study would be needed to establish that point and to identify the drugs or drug groups.

Drugs Other Than Alcohol: How Serious a Highway Safety Problem?

Having acknowledged its limitations for drawing broader inferences, the fact remains that this study is the only American (U.S.) one that has examined, in injury-producing accidents, the crash-relevance of a comprehensive group of drugs which experts have thought likely to impair drivers. Consequently, it is worth asking what the implications of the results would be if upheld in more generally represented samples.

The incidence of non-alcohol drug involvement was not much below alcohol involvement. Altogether, 21.9 per cent of the drivers had substances other than alcohol in their blood (Table 14). Since there were fewer accidents than drivers (because of crashes with two or more "in" drivers), this figure translates to 22.8 per cent of all accidents. There were 472 accidents in the "in" driver sample, but there were in those accidents 359 other drivers who never appeared at the Rochester General Hospital, hence no blood samples were obtained from them. Undoubtedly, some of these drivers had substances in their blood, and more than 23 per cent of the accidents involved substances other than alcohol. The proportion is not small.

But having stated that, it must be acknowledged that in apparent impairment effects, nonalcoholic drugs seem to be a problem considerably smaller than the alcohol one. But how much smaller? To get an idea, the culpability results may be used. In Chapter 6, it was found that 42.5 per cent of the drug-free drivers were judged culpable or culpable/contributory. For any of the substance groups, it may be assumed* that the substance in the drivers' blood

*Caution: This assumption and the attribution of responsibility are only for the purpose of arriving at a crude estimate with these limited data.

was responsible for the proportion of culpable drivers above 42.5 per cent. For example, of the 13 low-BAC-only drivers, 69.2 per cent were culpable or culpable/contributory. To alcohol may be attributed the responsibility for (.692 - .425) x 13 culpable drivers. Considering both alcohol-only groups, alcohol is assigned the responsibility for culpability as follows:

Low BAC :	(.692 - .425) x 13 =	3.5
High BAC:	(.902 - .425) x 61 =	29.1
Total		32.6 culpable drivers

For substances other than alcohol, responsibility is attributed as follows:

THC:	(.764 - .425) x 17 =	5.8
Other positive:	(.583 - .425) x 24 =	3.8
Total		9.6 culpable drivers

(The above ignores the fact that the culpability rate for the "other positive" groups did not differ significantly from the drugfree drivers.)

Finally, the alcohol-plus-drugs combination is assigned responsibility for (.737 - .425) x 38 = 11.9 culpable drivers.

While these calculations are a somewhat crude exercise in assigning crash responsibility to substances, they do provide at least some perspective on the relative importance of alcohol and other drugs for crashes. Drugs without alcohol seem to contribute somewhat less than a third (9.6/32.6) of the safety problem attributed to alcohol alone.

In summary, while the overall incidence of nonalcoholic drugs was nearly as large as the incidence of alcohol, it appears that the drugs contributed to only a fraction of the accidents that alcohol did. It appears that nonalcoholic drugs are a minor highway safety problem compared with alcohol. But since alcohol is a problem of great magnitude, the drug problem may yet be found a significant one.

Is There a General Dimension of Impairment?

One of the intriguing ideas arising from the analyses in Chapter 7 is the resemblance of alcohol impairment to the effects of other factors. While inferring crash risks without data on exposure is itself a risky business, the implications, if upheld, could lead to broadly beneficial countermeasures. Specifically, if alcohol impairment is similar to the "impairments" of drivers created by darkness, slick road surfaces, and old age, it just may be that highway or vehicle countermeasures that will reduce crash risks for one of the impairments will also reduce the risks due to one or more of the others. Better lighting and improved signing on curves, for example, may help not only drunk drivers, but sober drivers at night and elderly drivers at all times, as well. These possibilities are, to be sure, highly speculative and based on very limited data. But the concept of developing countermeasures applicable to a broad range of impairments may be a powerful one, for it opens up the possibility of developing highway or vehicle countermeasures that would reduce alcohol-involved accidents without the unpalatable notion that such measures are "only helping drunks." Furthermore, the benefits-to-costs ratios of more broadly applicable countermeasures should be superior to more limited ones.

It may be that driver detriments other than the few examined in this study would also resemble alcohol effects. Driver fatigue and illness, as well as external conditions like rain and fog, may similarly induce accidents.

Implications for Deterrence Countermeasures

As noted in the Introduction, the most common approach to countering the alcohol problem in highway safety has the objective of deterring people from driving while impaired. In Ross's (1981) review, he observes that effective deterrence requires an increased and probably exaggerated perception by the driving public of the chances of being apprehended when violating drunk-driving laws. This study has no obvious implications for affecting those perceptions, but it does have implications for ways to increase the real chances of apprehension of violators by police. Presumably, widely publicizing the fact of enhanced police capabilities would in turn affect public perceptions.

Data in this study revealed that the police indicated alcohol involvement for only half the drivers who were legally intoxicated, and only 16 per cent of those drivers received a DWI citation. Yet when the police did record alcohol involvement, they were nearly always right, consistent with findings elsewhere (Tharp et al., 1981). Further analysis revealed that the combined judgments of police and nurses successfully identified 67 per cent of the legally intoxicated drivers. These results point to the conclusion that most intoxication is behaviorally observable and, probably, well motivated and trained police could identify a large majority of intoxicated drivers. The data suggest that the police may be willing to indicate alcohol involvement only with the most noticeably impaired drivers, who are likely to have high BAC's. We are unable to go into this subject extensively, but there is evidence that police failure to report alcohol involvement is partially due to disincentives (Tharp et al., 1981). If the police were willing to use such skills, an improved effectiveness in identifying the intoxicated driver could be applied not only to accident drivers, but to those apprehended for other reasons. The ability to identify intoxication by driver behavior can complement the use of cues of vehicle behavior that indicate intoxication (Harris, 1980).

"Alcohol accident types" also provide a basis for identifying intoxicated drivers. As was found in Chapter 7, there are some circumstances in which chances seem very high that an accident driver had been drinking. These circumstances also might be used by police for requesting a blood test and would be applicable to injured drivers whose behavior cannot be observed. Perhaps, as Ross (1981) suggests, police are already aware of the times and places where drunk drivers are on the road. The completeness and accuracy of their knowledge is probably unknown, however, and the further identification of "alcohol accident types" may prove useful to enforcement of drunk driving laws.

Implications for Vehicle and Highway Countermeasures

As noted in the Introduction, making improvements in vehicles and/or the highways to reduce crash risks for the impaired driver is an idea that has existed for some time*, though it seems not to be widely supported. It did receive recent support, however, from Ross (1981), who warned that deterrence methods may turn out to be either ineffective or intolerably costly in the long run. By concentrating on vehicle and highway improvements, he notes, casualties originating from various causes other than alcohol may be reduced. In this argument he comes closer to the point we made earlier, viz. that highway and vehicle countermeasures may benefit drivers handicapped by various forms of impairment.

Countermeasures effective during or after crashes, e.g. restraint systems, are highly desirable and able to benefit drivers whether impaired or not. While such countermeasures are supported here, this study has no obvious implications for them. Instead, the results indicate the potential of precrash countermeasures, ones that will reduce the probability of a crash occurring. It is unfortunate that this study was not able to reveal more specifically the driver errors associated with alcohol and marijuana impairment. While the ideal of exactness was not achieved, the study did advance our knowledge or certainty about somewhat more general problems of the impaired driver. These have the following implications for countermeasures.

Countermeasures for reduced attention and alertness, including speed/distance misjudgments and inadequate tracking. This study reinforces the indications of other investigations that the predominant way by which alcohol increases crash risks is by reducing a driver's attention and alertness. While revealing problems of the impaired drivers, some of the data show conditions which seem to aid them. The fact that their right-curve crashes occurred

*For example, Moskowitz and colleagues (1976) recommended designing the highway system for impaired drivers. They recommended that fatigued, aged and inexperienced drivers be considered, as well as the alcohol-impaired.

with a third of the frequency of their left-curve crashes suggests that impaired drivers may be alert enough to recover vehicle guidance when there is sufficient opportunity. Lighting conditions also seemed to help them, for their proportion of single-driver crashes was substantially lower at night on lighted roads than on unlighted ones. Perhaps even the presence of oncoming vehicles serves an alerting or warning function for them, for although head-on-strikes appear as an alcohol collision type, that kind of crash was far less frequent than the single-driver ones.

With these considerations, kinds of vehicle or roadway countermeasures may be suggested for testing and evaluation.*

A. Guides and Warnings

(1) Warn driver of imminent road departure -- Rumble or drone strips at the road edge can inform the driver that his vehicle has crossed the road edge and is in immediate danger of a road departure.

(2) Indicate road edges more clearly -- Increasing road edge visibility, e.g., with wider paint strips, holds promise for keeping impaired drivers on the road (Macy et al., 1980). This or similar methods deserve to be field tested, particularly on roads where drunk driver roadside departures have been prevalent. Sharp curves are especially appropriate locations.

(3) Intensify and advance the warnings of curves, or signal the sharpness of curves -- Visual or auditory cues could be used to provide more intense warnings of curves than now generally exist. It may be helpful to begin them further from curves than is currently practiced, with repetition so as to "get through" to the impaired driver and give him a chance to react. Colors or reflectance intensity of curve warning signs may be used to signal sharpness of curves.

*Some of these ideas came from another C.F.S.I. project on "Identification and Testing of Countermeasures for Specific Alcohol Accident Types and Problems," Contract DOT-HS-9-02085. There may, of course, be additional relevant vehicle or roadway countermeasures which are not mentioned here.

(4) Warn of parked or stopped vehicles -- Reflectors on the rear of vehicles might be made more distinctive, through size or brightness. An increasing flicker effect when being approached might be especially effective.

(5) Warn of slower vehicles ahead -- Again reflectors might be devised that would produce a flicker effect when a vehicle was being overtaken. A high-technology countermeasure utilizing radar to activate warning devices might also be considered, though costs and possible health hazards from the radar waves may offset the benefits.

A related approach on expressways might be the requirement that all vehicles under certain speeds use their flashers.

B. Hazard Reductions

(1) Improve lighting -- While improved lighting on roads generally would be expected to reduce alcohol-involved crashes, it obviously is economically more feasible to limit lighting improvements to locations particularly hazardous to impaired drivers. While this study did not explore such locations to a great extent, the confirmation of curves as an impaired driver problem suggests the value of concentrating on curve lighting.

(2) Increase sight distance -- Since impaired drivers may too slowly recognize the existence of hazardous locations, increases in sight distance may give them a greater opportunity to perceive and react to the hazards.

(3) Increase radii of curvature -- While corroborating data is needed to show that impaired drivers are especially susceptible to difficulties with sharp curves, corroboration would support the idea that increasing radii of curvature is an appropriate alcohol countermeasure.

(4) Increase shoulder width on outside curves -- Since some impaired drivers were inferred as able to take advantage of recovery areas when departing their travel lanes, widening shoulders on the outside of curves may serve to reduce their left-curve crashes.

C. Arouse Driver

Since the hazards to the impaired driver are basically internal, the most fundamental and broadly effective approach would be one that makes him more alert. Most of the countermeasures suggested above presume the impaired driver to be sufficiently alert to respond to warnings, signals, noticeable hazards, recovery areas, and so on. The analyses of collision types with respect to BAC suggest that the very high-BAC driver may be so stupified as to benefit but little from such countermeasures. Reducing crash risks for the superhigh-BAC driver would probably be extremely difficult, and the current state of knowledge seems very limited on ways to arouse the severely intoxicated person. Needed would be a reliable method to detect the fact of impairment (e.g. through steering wheel reversals) as well as a method that will arouse the driver (e.g. through sound signals, taped voice warnings, electrical stimuli, air blasts, etc.). Should such methods become technically feasible, their required installation in vehicles of DWI offenders (at the offender's expense) might be considered.

Countermeasures for speeding and/or reckless driving. While aggressive, disinhibited driving was not clearly evident in this study, the prevalence of apparently out-of-control crashes among intoxicated drivers suggests the possibility of speeding and recklessness. It is difficult to conceive of vehicle or highway countermeasures that would be primarily addressed to this problem, though some of the previously mentioned ones would probably help to a degree.

While vehicle-installed devices might be considered for warning the driver of speeding or recklessness, getting the disinhibited driver to heed those warnings may be an unrealistic objective. This is an area needing further basic research before vehicle-highway countermeasures can be suggested.

10. CONCLUSIONS AND RECOMMENDATIONS

While necessarily qualified because of the limitations cited in the previous chapter, certain conclusions may be made. They are presented below and followed by recommendations.

Substantive Conclusions

(1) Alcohol continues to be a major highway safety problem; its 25 per cent incidence in this study and high associated culpability rate is consistent with results in other studies of injured drivers.

(2) The 22 per cent combined incidence rate for all other drugs approached that of alcohol, though the incidences of most specific drugs were small.

(3) As to tetrahydrocannabinol, the marijuana-hashish ingredient:

(a) Judging by results in this study and in an Ontario driver fatality study (Warren, et al., 1980), THC may be the second most common substance in incidence, though that rate (9.5 per cent) was less than half the alcohol rate in this study.

(b) Also consistent with the Ontario results, elevated culpability rates were found among drivers in whose blood only THC was found; while data were limited, culpability rates tended to be positively related to THC concentrations.

(c) No special collision types were associated with THC.

(d) Regarding THC, it must be emphasized that the reliability of the results and the relation of THC blood levels to crash-relevant impairment need to be studied with a larger and more representative sample; to determine THC relative crash risk, an exposure sample of matched controls is also needed.

(4) As to tranquilizers such as diazepam (Valium®) and chlordiazepoxide (Librium®):

(a) Consistent with results in the Ontario study, tranquilizers were the third most frequent drug group*, with an incidence rate of 7.5 per cent.

(b) Contrary to the findings in the Ontario study, there was no evidence in this study that tranquilizers played a role in the crashes.

(c) The question of tranquilizers as a highway safety problem remains open, to be settled only with more extensive study.

(5) As to other drugs: While results hinted at the possibility that some among the fourteen other drugs detected were impairing, whether any are significantly so could not be determined in this study.

(6) Further as to alcohol:

(a) Alcohol-involved drivers were most overrepresented in these collision types:

- Passive roadside departures, i.e. crashes involving driving off the side of the road;

*Outside of salicylate (aspirin), found in the Ontario study, but not examined in this one.

- Active roadside departure, i.e. crashes involving apparently out-of-control vehicles;

- Single driver forward impacts, e.g. hitting parked vehicles;

- Rear-end strikes, i.e. running into the rear of another vehicle;

- Opposite-direction strikes, e.g. head-on impacts and sideswipes.

As a group, single-driver crashes (the first three above) were far the most prevalent among alcohol-involved drivers.

(b) Crashes of alcohol-involved drivers include a disproportionate number on curves; the possibility that impaired drivers have especial difficulty with sharp curves and left curves is suggested, but this needs investigation with a larger sample.

(c) Alcohol-involved drivers were not only overrepresented in night crashes; they seemed to have especial difficulty on unlighted roads.

(d) Alcohol crash-relevant impairments are inferred to be primarily decrements in alertness, attention, tracking ability (guidance) and possibly speed-distance judgments; alcohol impairments resemble ways by which darkness, slick road surfaces, and old age impair <u>sober</u> drivers.

(e) Crash circumstances in which alcohol-involved drivers were most likely to be found were single-driver crashes occurring on a curve in the early morning hours.

(7) Both police and emergency department nurses were found nearly always correct in their positive judgments of a driver's alcohol involvement; however, they failed to make positive judgments on a majority of alcohol-involved drivers. The superiority of their pooled judgments indicates the possibility of improving drunk driver detection rates based on behavioral cues.

Methodological Conclusions

(1) Judgments of driver culpability as performed in this study* can have high intercoder reliability and they appeared positively related to driver BAC, similar to the way BAC is related to relative crash risk derived from accident and exposure data in other studies.

(2) Collision types can be judged in detail and with high intercoder reliability using the CALAX system, which captures the role of the individual vehicle in crashes. Collision type analysis seems useful for inferring the forms of crash-relevant impairment (although it cannot be conclusive).

(3) "Alcohol accident types," defined as sets of circumstances in which alcohol-involved drivers are most prevalent, hold promise as proxy indicators of alcohol involvement. These may be useful in analyzing mass data files such as in the National Accident Sampling System and the Fatal Accident Reporting System, where complete BAC data on drivers are not always available.

*Culpability analyses and related analyses using induced exposure have been made in various ways, sometimes assuming all drivers in single-vehicle crashes to be culpable (Thorpe, 1967; Carr, 1969), sometimes using police judgments of culpability in two-vehicle collisions (Carr, 1969). Culpability judgments have also been made for pedestrian accidents (Blomberg, et al., 1979). Our conclusion does not address the merits of these approaches, nor can it pertain to procedures where the reliability of judgments is unknown.

Recommended Applications of the Results

(1) More extensive development and testing of roadway and vehicle countermeasures attuned to the impaired driver is strongly recommended. Evaluation should include effects not only on alcohol-involved drivers, but on sober ones as well. Testing in darkness and with sober fatigued drivers and with sober elderly drivers are recommended conditions to include, among others. Simulation, laboratory experiments, and controlled road tests would be appropriate for preliminary assessments, with field tests in areas of prevalent drunk driver crashes for more definitive evaluations. The following are recommended for development and/or evaluation (cf. Chapter 9 for details):

- Signals that warn driver that road departure is imminent;
- Clearer delineation of road edges, especially at night;
- Intensified and advanced warnings of curves;
- Clearer warnings of the severity of curves;
- Improved rear reflectors on vehicles, preferably ones that signal overtaking;
- Improved lighting on curves, especially sharp ones;
- Increased sight distances;
- Increased radii of curvature on curves;
- Increased shoulder widths on outside of curves.

(2) Indications that many drunk drivers in crashes receive no citations for DWI, combined with findings elsewhere that apprehended violators are insufficiently cited, lead to the recommendation that ways be found to increase police utilization of the arsenal of methods now or potentially available to them to identify intoxicated drivers. These include:

(a) Salient behavioral indications, e.g. alcohol on breath, which seem already to be used by police in identifying the more inebriated drivers;

(b) More sophisticated behavioral tests, e.g. horizontal gaze nystagmus (Tharp, et al., 1981);

(c) Impairment-indicating vehicle actions (Harris, 1980);

(d) Alcohol accident types, as examined in this study.

Realistically to expect police use of these methods will require not only training but appropriate incentives as well. Discussion of those incentives is beyond the scope of this report, but factors that encourage and discourage police reporting of drunk drivers would have to be considered in efforts to increase the technical capability to detect those drivers.

Recommended Further Studies

Many useful studies suggested themselves in the analysis of the data, but only the ones potentially most valuable are listed below.

(1) Expanded injured driver study of alcohol and drug involvement -- Because of its limitations, particularly in location, sample size, and omission of eligible drivers, this study leaves uncertainty on some important issues it raised, and it was unable to address other important matters. Consequently a

similar but improved study is recommended, one whose data may be combined with this one for a broader data base.

The major issues are:

(a) Marijuana: Does it really impair drivers sufficiently to cause crashes? At what THC levels? What is the incidence of those levels among crash drivers? What collision types are associated with THC impairment?

(b) Tranquilizers: Are there conditions, dosages, or individuals for which tranquilizers increase crash risks or driver culpability? Is or is not tranquilizer use a significant highway safety problem?

(c) Low incidence drugs: Which, if any, low-incidence drugs significantly impair drivers?

(d) All non-alcoholic drugs: What is their net effect for the highway safety picture?

(e) Alcohol: What kinds of locations are especially hazardous to alcohol-impaired drivers? What types of curves trouble them? Is their crash risk increased (relative to sober drivers) at any particular kind of straight road sections?

An improved study to address these questions would have the following design features:

- Larger and more representative sample;
- Adequate rural as well as urban accident subsamples;

- One or more hospitals that obtain blood samples routinely on injured drivers, if there are such hospitals;

- Breath analyzer as a backup when a blood sample cannot be obtained;

- Scene data on characteristics of the accident locations.

Such a study should be made more cost-effective by using some of the lessons gained in this study (See Appendix E). While it is recognized that collecting blood samples from drivers on the road may present serious problems, the feasibility of collecting such exposure data for drug crash-risk analyses should be determined.

(2) Fatal driver study -- The incidence and impairment effects of alcohol and drugs in fatal accidents should be studied, at least for driver fatalities. Results may be significantly different from those for injured drivers, e.g. in collision types, in indicated tranquilizer impairments. A good mechanism would be to use the sites of the National Accident Sampling System (NASS) to obtain a nationally representative sample of driver fatalities. As with the injured-driver study, it is recommended: (a) that the fatal study include a larger, more representative sample; (b) that it include detailed scene data for analysis of hazardous locations; and (c) that the collection of exposure data be considered.

(3) General impairment literature review -- Extant research on driver fatigue effects, impairments of the elderly, effects of darkness, fog etc., should be reviewed along with studies of alcohol and drug impairments to determine if there is convincing evidence of aspects common to several kinds of impairment, which may suggest common vehicle or roadway countermeasures.

(4) Alcohol accident research secondary analyses -- Several studies besides this one have collected BAC data on drivers in crashes, and some have collected exposure data as well.* These would provide valuable and low-cost data sources to determine the reliability of the potentially more important alcohol findings in this study. The secondary analyses should examine:

- The relation of collision types to BAC;
- Collision types within circumstances, for sober and alcohol-involved drivers;
- Alcohol accident types;
- The relation of culpability rates to relative crash risks for BAC groups.

(5) Replicate Damkot et al. (1977) study -- The only study found to examine the relation of driver BAC to vehicle travel speed should be replicated, with data analysis determining if alcohol is associated with excessively high and low speeds, with particular attention to driver age and sex. Such a study should finally answer the questions of whether alcohol induces some drivers to speed, and if so, what proportion react that way.

(6) Assess alcohol involvement routinely in vehicle/highway countermeasure evaluations -- Many countermeasures evaluated by NHTSA and FHWA may be especially effective with alcohol-impaired drivers. By the simple addition of police-indicated alcohol involvement into the data base of evaluations using accident data, discovery of such countermeasures may be facilitated.

*Studies with exposure data include those by Borkenstein, et al. (1964) and Farris, et al. (1976), and others cited by Hurst (1974). Studies with BAC but not exposure data include those by Filkins, et al. (1970) and Warren, et al. (1980, 1981).

Recommended Research Methods

(1) Culpability analysis -- Should the collection of exposure data prove infeasible, it is recommended that the culpability analysis used in this study be used in subsequent studies on the role of drugs. This will allow for comparisons with this study and provide some basis for suggesting crash-relevant drug impairment.

(2) Collision types -- Since the CALAX collision type system was found to be easily learned and to have high intercoder reliability, it is recommended for consideration in any research requiring collision type analysis. In simplified form (e.g. CALAX1R), its use may be considered for incorporation into standard police accident reports.

(3) Assessing alcohol involvement in NASS and FARS -- It is recommended that "alcohol accident types" be considered for surrogate measures of the extent of alcohol involvement in the National Accident Sampling System and the Fatal Accident Reporting System. After establishing "alcohol accident types" more definitely from secondary analyses [see Recommendation (4) in previous section], the proportion of main types in NASS and FARS could be weighted by the expected proportions of drinking drivers within each to arrive at an overall estimate of alcohol involvement. Police reports of alcohol involvement should also be used, while recognizing that the police reports may overlook many drivers who had been drinking. Used complementarily, the two methods may provide a way to monitor the extent of alcohol involvement in crashes over time. This approach could be used to evaluate the success of efforts to deter motorists from driving while impaired.

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